ENTREPRENEURIAL UNIVERSITIES IN A KNOWLEDGE-BASED ECONOMY: THE CASE OF NATIONAL UNIVERSITY OF SINGAPORE.

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Summary

In the emerging 'New Economy', where knowledge and ideas are considered as strategic components of economic advantage, it stands to reason that the university, as the traditional repository of knowledge, would take on a more direct role in the economy. One key reason for this is the advance in information and communication technology (ICT), which leads to a shortening time frame between investigation and utilization, as well as an increasing recognition for the twin theoretical and practical impetuses to science and technology (S&T) research and innovation. Henceforth, the university, which up to now was a relatively distinct and separate institutional sphere from the industry, can now assume tasks in the development of new technologies that was previously in the domain of the other.

However, in crossing the traditional boundaries to link up with the industry, the university has to make its multiple purposes compatible with each other. Major strides in this area include the promotion of academic entrepreneurs in forming and incubating firms, and the organizational initiatives of academic administrators in facilitating technology transfers and protection of intellectual properties. Driving this trend further is a new social contract that is being drawn up between the larger society and the university. Unlike the past, public funding for the university today is made dependent upon a more direct contribution to the economy. All this creates a new spiral model of innovation, one where there are multiple reciprocal linkages at different levels of the capitalization of knowledge.

Therefore the aim of this thesis is to examine the role of the National University of Singapore (NUS), in light of Singapore's shift towards knowledge based capitalism.

NUS has traditionally been a teaching and research university. However, considering the recent emphasis in life sciences and developments in the university sector; where NUS has been increasingly encouraged to engage with the industry and to play a more productive role in the economy, the context of emerging triple helix relations between NUS, industry and government would be examined to understand NUS's emergence as an entrepreneurial university. This in turn also provides an opportunity into exploring the features of NUS as an entrepreneurial university.

Finally, this approach opens up windows of reflection into the implications and future role of the university. In a period where universities enjoy an enhanced standing for economic contribution, it is important to ensure that the university is well adapted and organized to take advantage of this opportunity. Moreover, shifts towards an entrepreneurial role are not without their complications and an understanding of some of the potential issues that may arise would better position NUS in this changed environment and guide it to its future potential role.

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INTRODUCTION
AND RESEARCH QUESTIONS

Introduction and Research Questions

Since the Industrial Revolution, the pace of globalization [1] has accelerated. Spurred by developments in "space shrinking" information and communication technologies (ICTs) (Dicken, 1992), companies can now easily co-ordinate their core activities on a global scale; from allocating labour intensive production to low-labour cost market structures to the entering of new markets for the provision of mass production of locally catered goods. In doing so, the global economy becomes a "networked" and "informational" one (Castells, 2000), where companies are not only linked to other business networks, but are also increasingly dependent on the productivity of informational flows in these networks. In other words, economies today are becoming more knowledge based, with technological innovations being brought to the forefront.

This phenomenon is most apparent in the field of science and technology (S&T). Advances in ICT have not only led to a diminishing gap between the time frame of investigation and utilization, such that there is an increasing recognition for the twin theoretical and practical impetuses to S&T research and innovation, but also created an *Endless Transition* for innovations in S&T. Recently, for example, the completion of the Human Genome Mapping Project2, has provided an endless amount of possibilities; at the crossroads of biology and computing lay new technologies and frontiers that are now

[1] For further discussion on the concept of globalization, see Beck (1999) and Held and Mcgrew (2003).

[2] Begun formally in 1990, the U.S. Human Genome Project was a 13-year effort coordinated by the U.S. Department of Energy and the National Institutes of Health. The project originally was planned to last 15 years, but rapid technological advances accelerated the completion date to 2003. Project goals include identifying all the approximately 20,000-25,000 genes in human DNA, determining the sequences of the 3 billion chemical base pairs that make up human DNA and storing this information in databases.

perhaps only at the conceptual stage, as well as numerous opportunities for income in various areas such as medicine, health care and insurance. As such, advanced economies worldwide are now rushing to compete in the area of S&T. In the United States (US), research consortiums that strengthen research collaborations between industry, universities and federal laboratories, and has contributed to the growth of the US economy, have been established to tap new innovation opportunities. In Japan, the Science and Technology Basic plan of 1996 recommended a more flexible employment scheme for researchers in government research centres so as to encourage further personnel mobility and the likely diffusion of knowledge that accompanies it (Science and Technology Agency, 1998). In a nutshell, whoever has the capability to continuously generate S&T innovations would lead the global knowledge economy.

Over the last three decades, Singapore has achieved a remarkable economic growth (See Table 1.), evolving from a colonial entreport to an economy with a sophisticated industrial structure. In this development, continuous technology expansion has played a critical role. The combined efforts of attracting multinational companies (MNCs) and investing in education and skills training, as well as encouragement of technology diffusion from the MNCs to the economy, has led to Singapore acquiring a considerable technological capability. Nevertheless, a technological gap with the advanced economies still remains because innovative capability is still weak (Goh, 1996).

Table 1: Aggregate Economic Growth Performance of Singapore's economy, various years.

	Percentage (%) real growth per annum				
	1960-1970	**1970-1980**	**1980-1990**	**1990-1993**	
Gross Domestic Product	8.7	9.4	7.1	7.5	
Productivity	-	4.3	4.8	3.7	
	1960	**1970**	**1980**	**1990**	**1993**
Gross National Product per capital (S$) (at current prices)	1330	2825	9941	20090	24871

Source: Wong (1995)

Recently, however, in Singapore's push towards the life sciences, the promotion of S&T innovation has not only accelerated but has also begun to encompass the two main local universities, namely Nanyang Technological University (NTU) and the National University of Singapore (NUS). According to the previous Minister of Education, Teo Chee Hean (2000), local universities should no longer be considered as 'ivory towers' but "engines of innovation" because of their knowledge foundation and expanding linkages to other universities, industries and government, at both local and global levels. Moreover, he proposed for a major restructuring of the university sector such that universities can play a more productive role in the economy.

NUS has however not always held this role. It had its roots in teaching, and subsequently expanded into research and development (R&D) as Singapore shifted up the technological ladder. But the development of academic research does carry within itself the seeds of future economic and social development in the form of human capital, tacit knowledge and intellectual property. As such, recently, in NUS, channelling knowledge flows into new sources of technological innovation has become an academic task, changing the structure and function of NUS. This change in emphasis from a sole concentration on the production and dissemination of knowledge to technology transfer and the formation of firms places NUS in a new alignment with the productive sector.

In addition, this also indicates that a new social contract between the NUS and the larger society is being negotiated in a much more specific term than the old one. The former was based on a linear model of innovation, presuming only the long term contributions of academic knowledge to the economy. Now both long and short term contributions are seen to be possible due to the advances of ICT. All this creates a spiral model of innovation; one where there are multiple reciprocal linkages at different stages in the capitalization of knowledge.

Research Questions

Although there have been a growing number of academics who are interested in technological change, their innovation process and their impact on economic growth in Singapore, few have actually considered the role of the university in this context. Studies (Wong 1999 and Hu and Jang-sup, 2002) examining the innovation system of Singapore do acknowledge that the universities are playing a more important role in R&D but do not provide a clear idea as to what position the university should adopt in this changed economy.

In light of this, the primary research question of this thesis would be: What is the role of NUS in Singapore's knowledge based economy? Three auxiliary questions would be: Why has NUS undertaken this new role? What are the features of this new role? Also what are the implications of this new role? I intend to answer these questions by documenting and examining the historical development of NUS in the context of Singapore's changing S&T landscape. That is, I am interested in examining the evolving relationships between key players in the economy, namely the industry, university and government, using the triple helix model, as S&T becomes increasingly important in the knowledge based economy. Moreover, to support these observations and analysis, in-depth interviews would be held with the respective personnels. In doing so, I would be able to identify and examine the features of NUS today and provide further insight into the implications and direction for the future of this new role.

Following this, **Chapter One** discusses some of the key theoretical issues in a knowledge based economy, especially with regards to innovation. The traditional understanding of innovation can no longer hold, but instead a network perspective, with a focus on communication patterns must be adopted. These changes are further examined in the field of science and technology (S&T), where the relationships between key actors like the university, industry and government are changing.

Chapter Two explores the conceptual tools that can be used to examine this changed economy. I will argue that the triple helix model would best capture the dynamism of this perpetually innovative economy. **Chapter Three** explores how universities in some countries have been affected by these changing relations. In particular, the emergence of an entrepreneurial university is becoming an increasingly common phenomenon. Features of the entrepreneurial university are highlighted and discussed. **Chapter Four** then narrows this discussion to the context of Singapore. S&T policies in Singapore have changed over the years and this is reflected in the changing interactions between the university, industry and government. The initial transformations of NUS are also documented.

Chapter Five continues this by looking at the changes NUS has taken in response to knowledge based capitalism. I would demonstrate that NUS is embarking on an entrepreneurial role. These changes are mapped out according to the methodology proposed. Finally, the implications of these changes and the future of the university are explored in **Chapter Six**.

CHAPTER ONE

SCIENCE AND TECHNOLOGY IN A KNOWLEDGE BASED ECONOMY

Chapter One: The Science-Society Contract in a Knowledge based economy

1.1. Introduction

Knowledge, as embodied in human beings and in products and processes, has always been central to economic development. As Drucker (1998) observes, knowledge was a key factor in the Industrial Age, where the developments of the steam engine, electricity and telephone, all helped to shape and change the world economy. The key difference today however, lays in the degree of incorporation of knowledge into economic activities; to the extent that it induces “profound structural and qualitative changes in the operation of the economy” (Houghton and Sheehan, 2000, p. 1).

The Organisation of Economic Co-operation and Development (OECD) economies today, for example are more knowledge intensive then before. This is reflected in economic performance, where in the majority of OECD economies, high and medium technology-intensive exports accounted for much of the growth in trade over the past decade. In all OECD countries, these exports grew more rapidly than total manufacturing exports (See Table 2). For industries, the high tech share of OECD manufacturing production grew, jumping from a share of 19.7% in 1992 to 26.1% in 2001 (See Table 3). At the same time, investments are also being directed towards knowledge intensive activities such as research and development (R&D), higher education and software (See Table 4).

Table 2: Average Annual Growth rate in Percentage (%) of high and medium technology, and manufacturing exports in OECD economies, 1992-2001.

	High- and medium-high-technology industries[3]	High-technology industries only	Manufacturing
Iceland	24.4	32.0	3.7
Hungary	19.4	26.3	12.5
Czech Republic (1993-01)	17.1	24.5	13.0
Mexico	16.1	19.1	15.3
Poland	15.8	19.5	12.8
Ireland	15.8	17.6	11.2
Turkey	15.7	19.0	9.5
Finland	10.9	17.3	7.0
Slovak Republic (1997-01)	10.8	9.0	6.8
Greece	9.8	17.8	1.0
Korea (1994-01)	8.3	8.5	6.4
New Zealand	8.3	8.0	3.9
Portugal	8.2	9.6	3.2
Canada	8.1	10.0	7.4
Australia	6.9	7.2	3.8
United States	6.9	8.1	6.4
Belgium	6.9	11.6	5.1
Spain	6.8	7.8	6.7
United Kingdom	6.2	9.6	4.6
Netherlands	6.1	10.1	3.6
Austria	5.2	9.3	4.1
Sweden	4.7	6.8	3.5
Norway	4.5	6.7	3.0
Denmark	4.5	6.9	2.1
France	4.4	6.8	3.2
Italy	4.4	5.0	3.8
Germany	3.9	6.9	3.2
Switzerland	3.4	5.8	2.8
Japan	1.7	1.8	1.6

Source: OECD *Science, Technology and Industry Scoreboard*, 2003.

[3] High tech industries refer to the aircraft and spacecraft, pharmaceuticals, office, accounting and computing machinery, radio, TV and communications equipment, medical, precision and optical instrument industries. Medium high tech industries refer to the electrical, machinery apparatus, motor vehicles, trailers and semi-trailers, chemicals (excluding pharmaceuticals), railroad and transport equipment, machinery and equipment industries.

Table 3: Technological Share in Percentage (%) of Total Manufacturing Trade in OECD economies, various years.

	High Technological	Medium High Technology	Medium Low Technology[4]	Low Technology[5]
1992	19.7	38.9	16.5	24.9
1993	20.6	38.4	16.2	24.7
1994	20.9	38.9	15.8	24.3
1995	21.2	39.1	16.0	23.6
1996	21.6	39.4	15.6	23.3
1997	22.7	39.2	15.4	22.6
1998	23.9	39.2	14.8	22.0
1999	25.1	39.2	14.1	21.5
2000	26.9	38.1	14.7	20.3
2001	26.1	38.3	14.7	20.8

Source: OECD *Science, Technology and Industry Scoreboard*, 2003.

[4] Medium low technology industries refer to the building and repairing of ships and boats, rubber and plastic goods, coke, refined petroleum products and nuclear fuel, basic metals and fabricated metal products industries.

[5] Low technology industries refer to manufacturing of pulp, paper, paper products, printing and publishing, food products, beverages and tobacco, textiles, textile products, leather and footwear, and wood and products of wood and cock industries.

Table 4: Investment in Research and Development (R&D), software, higher education in Percentage (%) of Gross Domestic Product in 2000 and Average Annual Growth in percentage (%) for investment for all three sectors in OECD economies, 1992-2001.

	R&D	Software	Higher Education	Annual average growth (1992-2000)
Greece (1999)[6]	0.7	0.3	0.7	8.8
Mexico (1999)	0.4	0.4	1.0	-
Poland	0.7	0.7	0.5	-
Portugal	0.8	0.6	0.8	8.3
Italy	1.1	0.7	0.5	1.8
Slovak Republic (1999)	0.7	1.0	0.7	-
Spain	0.9	0.6	0.9	6.4
Hungary	0.8	1.4	0.9	3.4
Ireland	1.1	0.7	1.2	10.8
Czech Republic	1.3	1.6	0.7	-
Norway	1.5	1.4	1.1	4.5
Austria	1.8	1.3	0.8	6.7
Australia	1.5	1.4	1.1	4.5
United Kingdom	1.8	1.8	0.6	5.0
Belgium (1999)[7]	2.0	1.6	0.8	-
France	2.2	1.7	0.7	4.6
Japan[4]	3.0	1.1	0.6	3.4
Netherlands	1.9	2.2	0.7	6.0
Germany	2.5	1.6	0.6	4.3
Denmark (1999)[3]	2.2	1.7	1.1	7.6
Switzerland	2.6	1.9	0.6	4.0
Canada[4]	1.9	1.7	1.8	4.0
Korea	2.7	0.5	2.3	-
Finland	3.4	1.7	1.1	8.8
United States[8]	2.7	1.8	2.3	6.1
Sweden	3.9	2.4	0.8	9.7

Source: OECD *Science, Technology and Industry Scoreboard*, 2003.

[6] Average annual growth rate refers to 1992-99.
[7] Data for higher education only include direct public expenditure.
[8] Post-secondary non-tertiary education is included in data for higher education.

These trends are leading to revisions in the traditional theory of economic growth. Traditionally, “production functions” consist of key elements such as labour and materials; with knowledge being a more external influence on production. Today however, analytical approaches are constantly being developed to include knowledge more directly into the production function. Furthermore, investments in knowledge are characterised by increasing returns; the productive capacity of other factors of production will expand, leading to the transformation and creation of new products and processes, making them the key to long term economic growth (Stevens, 1998).

In order to gauge the implications for this new economic paradigm, it is first necessary to appreciate how knowledge is changing the traditional inputs. The first section of this chapter will therefore focus on the nature of knowledge and its role as a factor of production. We will take a close look at knowledge itself and the key characteristics that determine its economic value. The important role of information and communication technology (ICT), networks and innovation is then discussed.

The second section of this chapter will draw the discussion into the arena of Science and Technology (S&T). The phenomenal growth of computers, biotechnology and so forth that are leading the knowledge based economies are all driven by scientific knowledge. Recent growth of transdisciplinary fields like nanotechnology and artificial intelligence further drives this trend. All these have manifold implications for the creation, dissemination and use of S&T knowledge.

Understanding these implications begins with an examination of the concepts of science and technology. Due to ICT, there is now a shortening time frame between investigation and utilization, as well as the increasing recognition for the twin theoretical and practical impetuses to S&T research and innovation. The impact of this on the creation and dissemination and use of S&T (in terms of technopreneurship) is then discussed. This chapter will finally conclude by giving an overview of the S&T knowledge infrastructure in a knowledge based economy.

1.2.The Knowledge Based Economy

1.2.1. Knowledge as a Factor of Production

The Concept of Knowledge

The terms *information* and *knowledge* have often been used interchangeably to describe the phenomenon of the knowledge based economy. There are however, distinctions between these two concepts. Information, for one, often takes the shape of data arranged in a meaningful pattern, and will remain passive and inert until used by one who has the knowledge to process and interpret them. Knowledge, on the hand, therefore empowers its users with the capacity for intellectual or manual action; basically boiling down to cognitive capacity (David and Foray, 2002).

The full implication of this distinction, especially between information and knowledge, however becomes clearer when one looks at the conditions governing the reproduction and dissemination of information and knowledge. With information, the cost of reproduction and dissemination amounts to no more than making copies. For knowledge, this process is a much more complicated and expensive procedure because cognitive capacity is not easily articulated explicitly and transferred to others (Polanyi, 1966). Here, we are actually referring to the *tacit* or *implicit* element of knowledge that can only be acquired through a "master-student" system or on interpersonal relations between communities or practice or members of similar professions. This means that if contact between older and younger generations is broken up, professional communities would lose their capacity to act as the storage and disseminators of knowledge. Henceforth, reproduction grinds to a stop and the knowledge in question suffers the potential of being lost.

There is however, another element of knowledge, namely *codified* or *explicit* knowledge. Knowledge is codified when it is recorded or disseminated in the form of symbols (for example, drawing and writing) or embodied in a tangible form like tools and equipment. Through the process of codification, knowledge is detached from the individual, such that the communication and memory capacity is independent of the human being; reducing it to information. Therefore, the extent in which codified knowledge can be reproduced and disseminated depends strongly on the degree in which the codification process can accurately and precisely capture the essence of the knowledge to be reproduced and disseminated.

According to Saviotti (1998), a key factor in determining this is the appropriability of knowledge. The appropriability of knowledge depends on the amount of codification, the fraction of the population of agents that know the code, and the dissemination of knowledge among the agents who are potential users of this piece of knowledge. Generally, as knowledge matures, it becomes more codified and evenly distributed among agents, and less appropriable. Therefore if appropriability is to be continued as knowledge is increasingly codified, it is necessary to protect it through a variety of mechanisms. The establishment of formal intellectual property rights (IPRs), through patents, trademarks and copyrights are one way of protecting codified knowledge. With the relevant contractual arrangements, codified knowledge can be easily transferred across time and space.

The Drive to Codify Knowledge

The codification of knowledge is however not something new. In most ancient cultures, counting devises were the first signs of attempts to codify knowledge. Early systems of writing, such as the pictographic-ideographic variety in Egyptian hieroglyphs, that emerged around 3000 BC, permitted the recording of a broad range of information. Today, however, the scale of codifying knowledge has expanded to a larger scale.

According to Roberts (2001), the twin, non-mutually exclusive, economic and technological reasons are the key forces driving large scale knowledge codification. In a knowledge based economy, the assets that make up a firm's capital are embedded in its workforce and its organizational routines. Codifying knowledge would serve as a way of controlling the knowledge not only within the firm but also in the marketplace; where knowledge commodities can be exchanged. As described earlier, codified knowledge, like information can be easily disseminated. Hence the desire to reduce the cost of knowledge transfer in the market or within the boundaries of the firm encourages the codification of knowledge. Furthermore, codification enables the protection of knowledge via the presence of traditional IPRs.

This interest in protecting knowledge is encouraged by a variety of factors. As Robertson (1999) observes, unlike labour and capital which can substitute each other, nothing can substitute for knowledge except more knowledge. That is knowledge "encourages it own accumulation and renewal" (p. 29). In the simplest form, knowledge does not diminish; rather it possesses an inexhaustible capacity for growth. Furthermore, the knowledge embedded in the commodity loses value quickly, a process which Schumpeter (1939) identifies as “creative destruction”. For example, once produced, software can be made outdated quickly because it can be subdivided between a potentially infinite number of products (as software can never wear out). This development in turn promises acceleration in the rate of growth for stocks of knowledge due to higher rates of scrapping and obsolescence (OECD, 1996). One good indication of this is the shortening of the product life cycle. A good example of this is the accelerating pressure on Hewlett Packard (HP) from the 1970s till today. During the 1980s, 70 percent of HP’s orders came from products less than three years old but in the 1990s, that changed to products less than two years old. “…the lifetime of a product is simply getting shorter and shorter” (Platt, 1993. p.146).

For this, knowledge has increasingly become the primary source of competitive advantage. More importantly, the large expense necessary to create knowledge has provided a great incentive to protect it so that one can appropriate the maximum returns from investments in research and development (R&D). With codification, knowledge can be protected through contractual arrangements, reproduced at a low cost, disseminated among economic agents and easily quantified against a set of given criteria. In other words, the codification of knowledge facilitates its commodification.

The extent in which the codification of knowledge can occur is also inextricably linked to the availability of technology. Each technological development, from the printed book to the World Wide Web has increased the ease in which knowledge can be codified and distributed. The computer, for example, can codify a large amount of knowledge and transmit it across the local and global communication networks that it is linked to. This is in part due to the declining cost of ICT. For example, between the mid 1950s and the mid 1980s, the cost of computing power, as compared to the cost of manual information processing, fell by 800% percent, and between 1958 and 1980, the time required for a single electronic operation fell by a factor of 80 million (Porter and Millar, 1985). One result of this has been the emergence of an "information society"[9]; a society where the majority of workers are involved in the production, handling and distribution of information. Indeed, in 1900, less than 8 percent of the total workforce was engaged in data and information handling tasks. By 1980, this figure had risen to over 50 percent (Jonscher, 1994).

More importantly, access to codified knowledge is now on scale like never before. This is of great benefit because it has the capacity to contribute to the increased creativity and productivity of the workforce. Workers needing to solve problems can now draw on an enormous body of information and ideas and offer new solutions and opportunities to exploit knowledge assets; such as selling knowledge commodities via the web. Combined together, computing power and the codification of knowledge thus assist in the creation of endless new possibilities of knowledge.

In conclusion, the drive to codify knowledge by the mutually enforcing forces of economics and technology are best summed up by Morris-Suzuki's (1997a) observations of knowledge capitalism. In order to overcome the "inner limit of capitalism"[10], workers are now directed to the "incessant generation of new products and methods of production" (p. 58). Simply put, a worker's knowledge is now separated from the

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[9] Further explanation is provided in Webster (2002) and Castells (2000).
[10] Further explanation is provided in Mandel (1973) and Mandel (1975).

physical body and is embedded in new products such as software, to be sold in the market, producing a continuous supply of surplus value or profit for the capitalist. This trend means that firms and societies have little choice but to engage in a race with each other to come up with the latest and newest way of doing things or risk being outflanked, leading to what Suzuki (1997a) terms as a "perpetual innovation economy" (p. 18).

1.2.2. Networks in a Perpetual Innovation economy

Education and Learning

According to Saviotti (1998), knowledge is seldom completely tacit or completely codified. Instead a piece of knowledge is usually between completely tacit and completely codified. Furthermore, Polanyi (1966) argues that although "tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is *either tacit* or *rooted in tacit knowledge.* A *wholly* explicit knowledge is unthinkable" (original emphasis) (p. 7).

There are two implications for this. For one, dissemination of codified knowledge in terms of education will become increasingly important. For example, the receiver of codified knowledge needs substantial knowledge to process the information and reconstitute the information into useful knowledge. Any deficiency in the receiver's existing knowledge would lead to the inevitability of transcription errors; assuring that even the simplest efforts at reproducing knowledge would fall short of their goal (Cohen and Levinthal, 1989).

More importantly, there is a need to adopt a learning perspective. Codified knowledge does not represent complete knowledge. But it does become a learning programme that can help to reproduce knowledge. For example, when a junior technician receives a user's manual, he or she is not actually given directly the knowledge of "how to operate a machine". Instead, the manual will serve as a helpful tool in learning by doing. In some cases, if technicians have "learned to learn", knowledge reproduction can become almost instantaneous. More often than not however, in more complex cases, the codified knowledge will only provide partial assistance. Knowledge reproduction must still occur via training and practice.

The importance of learning is further expanded when taking into consideration the impact of ICTs. According to Corti and Storto (1997), advances in ICT have resulted in technical solutions identified by an actor to solve technical problems in a certain context to be easily transferred and adopted by another actor in order to solve similar problems in a context which is slightly or totally different. That is, new knowledge, in terms of ideas to develop new products or processes, can now frequently arise from the interface between different areas of technological knowledge (Von Hippel, 1977 and Hakansson, 1987). For this, firms face the need to network so as to provide opportunities for interactive learning; the constant transformation of tacit into codified knowledge and the movement back to practice where new kinds of tacit knowledge can be developed (OECD, 1996).

Networks and Innovation

The complex relationship between tacit and codified knowledge, as well as the resulting importance of education and learning, indicates that there is a need to re-examine the issues of individual versus collective repositories of knowledge. Due to the legacies of Adam Smith and Fordism[11], that emphasized the division of labour, economists, in approaching the creation of knowledge, were focused on the dichotomy between the entrepreneur and the inventor. Schumpeter (1943) for example, explores the dialectic of "managed knowledge creation" versus "entrepreneurship". During the last twenty years however, new entrepreneurial institutions have been created; many of which are connected to venture capitalists, whereby highly focused innovation plans are linked to entrepreneurial initiatives. The emergence of this trend suggests that a more complex institutional theory of innovation is needed.

The heritage of Schumpeter's (1943) work is also particularly evident in the historical development of the field of innovation studies. Early work in this field centred around the debate of the role of the individual creator and the traditional theory of innovation process. The traditional theory held that the innovation process of discovery proceeded through a fixed and linear sequence of phases. In this view, innovation begins with new scientific research, progresses sequentially through stages of product development, production and marketing, and terminates with the successful sale of new products, processes and services.

Today, however, because the process of knowledge reproduction and dissemination has accelerated, it is recognized that innovation can stem from many sources. That is, innovation can take on many forms, including applications of technology to new markets and incremental improvements to existing products. In this process, innovation can no longer be completely linear. Instead, it requires more communication and networks among different actors; firms, laboratories, academic

[11] For further explanation about the division of labour, see Smith (2000).

institutions and consumers, as well as feedback between activities like product development, marketing and manufacturing (Klein and Rosenberg, 1986).

As the creation and dissemination becomes increasingly organized through networks and network communication processes, the organization of economic activity would also follow a similar path. Gibbons et. al. (1994) observes how firms in the knowledge-based economy are continuously networking to promote inter-firm interactive learning and for outside networks and partners to provide complementary assets. These networks help firms to spread the risk and cost associated with innovation among a larger number of organizations; as created by the reduction of cycle times which results in the range of knowledge expanding and becoming more complicated such that companies no longer have the ability to cover all disciplines, acquire key technological elements of a new product or process, and to share assets in manufacturing, marketing and dissemination. As they create new processes and products, firms learn and determine which activities they can carry out individually, in collaboration with other firms, or in collaboration with universities and research institutions with the support of government.

In conclusion, the dynamic nature of knowledge is expressed in the complex relationship between tacit and codified knowledge. This in turn requires a more non-linear concept of innovation; where knowledge creation and dissemination would be increasingly organised around networks. In this, education and learning becomes of paramount importance.

1.3. The role of Science and Technology

1.3.1. The Creation and Dissemination of S&T knowledge

The Concept of Science and Technology

In light of the increasing contribution of S&T knowledge to economic growth, the discussion of the knowledge based economy will now be drawn into the arena of S&T. Science has always been an important source of knowledge. Traditionally produced at the universities and public research institutes and centres (PRICs) via basic research, it is generally distinguished from knowledge generated by more applied or commercial research which is closer to the market and the "*technology*" end of the spectrum. Despite this, in the United States (U.S), many important applications have emerged from academic research and, industry-university and PRICs collaborations. University researchers have made important contributions to scientific instrumentations and computer software, reflecting that university researchers are also "users" of technologies and their research activities frequently create new advances in applications in these areas[12]. This creates a two way flow between industry and universities and PRICs for the "*endless frontier"* of S&T research. In the knowledge-based economy however, this distinction between basic and applied research and between science and technology becomes increasingly blurred (OECD, 1996).

Central to this are the advances in ICT, which facilitate the increasing codification and commodification of S&T knowledge. There is now a shortening time frame between investigation and utilization, as well as the increasing recognition for the twin theoretical and practical impetuses to S&T research and innovation. Recently, for example,

[12] Further explanation of this can be found in Rosenberg (1992), who discusses the contributions of academic researchers to innovation in scientific instrumentation.

theoretical advances have occurred in tandem with the invention of devises or methodology in transistors, semiconductors and genetic engineering. Furthermore, new interdisciplinary disciplines have been created such as bioinformatics, whose components come out of the previous syntheses that created computer science and molecular biology. More recently, these two have themselves been brought together to form a new field in a continuing process of combination and recombination that has created other new fields such as behavioural economics[13]. Hence, in a perpetual innovating economy, S&T research is now more highly valued because of its capacity to bring forth the unexpected: the latest stunning and exciting new findings of research that are highly valued by not just policy makers and researchers but also the industry.

These trends in turn have an impact on the creation, dissemination and use of S&T knowledge.

The Creation and Dissemination of S&T knowledge

According to tradition, the creation of science has always enjoyed the protection of state funding, in return for which it provides a number of public goods in the form of knowledge and education, a relationship that science policy scholars such as Jacob, (2000a.) term as "science-society contract" (p.12) This contract however started to change during the 1980s, where declining economic performance and increasing world wide competition forced policy makers to narrow their perspectives on the role of science in achieving national goals to the single question of how to hitch the scientific enterprise to industrial innovation and competitiveness.

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[13] See Baxter (1988) and Baxter (1993).

Driving this change were two key reasons. Firstly, industry dependence on innovation has been accelerating dramatically since the Second World War, for a variety of reasons. For one, the creation of a scientific base for most engineering practice have permitted engineering to become more predictable, less risky and faster in its accomplishments. In many fields, inventions can be systematically managed into being. With computer modelling and simulation of both product designs and production processes, the performance and cost of products can be predicted without the traditional “bread board” design verification and pilot line production engineering (Kodama and Branscomb, 1999)

Secondly, the economic sectors with the most rapid growth are those closest to the science base; biotechnology, information technologies, and new materials. In the US, the Bayh-Dole Act of 1980, extended patent protection to publicly funded research, helping to strengthen the role of science in the innovation process and facilitated the early stages of industry-university collaborations. Since then, subsequent policies in this area have encouraged greater innovative performance. Furthermore, the economic sectors such as biotechnology, information technologies, and new materials are today rapidly becoming the top priorities for stimulation policies at the national level in the advanced industrial countries (OECD, 1980).

As a result, increasingly the creation and dissemination of S&T research has taken on a strategic slant so as to increase the efficiency of research by shifting resources, setting priorities and maintaining a tight system of output and performance control. Science has now become "…intertwined with the government in dealing with the social and political issues of the day" (Bell, 1973. p. 379) such that the links between science and government has become an intensively negotiated sphere of action, so much so that the "nature and the kinds of state support for science, the politicization of science, and the social problems of the organization of work by science teams" became "central policy issues" (Bell, 1973. p. 117).

This is evident in the S&T policy initiatives: and these initiatives generally fall into three areas, namely manpower development, support for the dissemination of knowledge and support of R&D (OECD, 1996 and Hu and Jang-Sup 2002). Firstly, for initiatives in manpower development, there is now further emphasis on the upgrading of human capital and the attraction of talented foreign labour. The economic benefits of an expanding knowledge base and network dissemination are only realized when they are adopted and applied by the labour force in the production of goods and services. The constant stream of technological advances in an advanced KBE compresses product cycles and speeds up the depreciation of human capital, making the upgrading of human capital even more critical. Hence, properly-trained researchers and technicians are essential for producing and applying both scientific and technological knowledge, and hence the education and training of scientists and engineers have stepped up.

Furthermore, as human capital is a key factor in the innovation process, openness to ideas from abroad and efforts to attract or use skilled human resources from abroad are also increasing. Countries such as Australia and the US have benefited substantially from the immigration of highly skilled personnel. According to the OECD (2003), in the U.S., the largest number of foreign-born scientists and engineers in the OECD area come from the United Kingdom and Canada and if non-OECD countries are taken into account, there are three times as many foreign-born scientists from China and twice as many from India as from the United Kingdom. This international source of skilled labour enables US to sustain rapid growth in the ICT sector, particularly in the software segment where human capital is the key input.

Secondly, to promote S&T knowledge dissemination, access to ICTs and linkages between key actors in networks to facilitate innovation. In many OECD countries, there has been a liberalization of telecommunications markets and regulatory reforms to facilitate investment in ICT. This allows the price of telecommunications to fall and facilitates the diffusion of ICTs (OECD, 2003). Even in Asian countries, these efforts have stepped up because latecomer economies like Taiwan sees ICT as an opportunity to catch up with the advanced economies. For example, the Taiwanese government has deregulated the telecommunications sector and network lines are being established faster (Chen, 2000).

In addition, scientific institutions, with their links to the industry, are important for technology diffusion and innovation. For this, the traditional bases for the production of S&T knowledge, which usually included the research institutions and universities, are now expanded to involve the industry. As part of the science policy initiatives, governments worldwide have intensified efforts on facilitating linkages between industry, the public sector and the university to better encourage innovation. One way in which they do this has been the reduction of funding for R&D at the university. This in turn encourages them to link up further with the industry. Secondly, there has been the creation of science parks, which provides a space for universities, industry and government to come together. Finally, there has also been the creation of trilateral organizations. Indeed, the structure of research councils is being modified to emphasize strategic areas, to promote synergies between disciplines and to involve the private sector. Some of these research councils have even been privatized. Industry is being asked to help define the areas in which research, including basic research, should be done. Government laboratories are forming joint ventures with the private sector.

For example, in the US, the government has established a semiconductor research consortium, SEMATECH, which strengthens research collaborations between industry, universities and federal laboratories, and has contributed to the growth of US microelectronics and computer industries (Braudo, 1999). In Japan, the Science and Technology Basic plan of 1996 recommended a more flexible employment scheme for researchers in government research centres so as to encourage further personnel mobility and the likely diffusion of knowledge that accompanies it (Science and Technology Agency, 1998). Clearly in the KBE, governments are earmarking more funds for science activities considered to merit priority by virtue of their economic and social relevance (such as IT and biotechnology).

With regards to the support of R&D, government's financial role in this has generally declined in favour of private sector funding. As seen in the Table 5, funding sources for countries in North America and the European Union for R&D between the years of 1981 and 1993 have increased consistently for the private sector but have generally declined in the public sector. In terms of performance, the industry also leads in R&D spending (See Table 6.). These trends were also reflected in Jankowski's (1999) study on academic research spending, alliances and commercialization in the United States. In his study, he concluded that funding sources from the industry, partnerships and alliances via centres and consortia with the industry has all increased and that in recent years, the proportion of total R&D financed by industry has increased relative to the government share in almost all OECD countries. In 1999, industry actually funded almost 60 per cent of OECD R&D activities and carries out about 67 per cent of total research**.**

Table 5: Trends in R&D Spending in Percentages (%) by sources of funds, 1981 and 1993, Various countries.

	Business Enterprises		Government	
	1981	1993	1981	1993
Japan	67.7	73.4	24.9	19.6
North America	48.4	57.6	49.3	39.6
European Union	48.7	53.2	46.7	39.7
Total OECD	51.2	58.8	45.0	36.2

Source: OECD *Science, Technology and Industry Scoreboard*, 2003.

Table 6: Trends in R&D spending by sector, in terms of performance, in percentage (%) in 1981 and 1993, Various countries.

	Business Enterprises		Government		Higher Education	
	1981	1993	1981	1993	1981	1993
Japan	66.0	71.1	12.0	10.0	17.6	14.0
North America	69.3	70.3	12.6	10.8	15.1	15.7
European Union	62.4	62.6	18.9	16.5	17.4	19.5
Total OECD	65.8	67.4	15.0	12.7	16.6	17.1

Source: OECD *Science, Technology and Industry Scoreboard*, 2003.

Following this trend in the OECD economies, the government's share in total R&D expenditure has also been declining in Asian economies such as South Korea and

Taiwan. In South Korea, 80 percent of R&D is financed by the private sector (Ministry of Science and Technology, Korea, 1999) and in Taiwan, the government finances only 45 percent share of R&D (National Science Council, Taiwan, 1996).

This declining share of government funded R&D however should not overshadow the policy emphasis that governments worldwide have placed on R&D (Hu and Jang-Sup, 2002). In the US, the Clinton administration has expanded various federal R&D programmes, such as the Advanced Technology Program, which provides matching funds to private firms to develop technologies that do not yet have a clear commercial market potential (Mowery, 1998). The Japanese government, under the Science and Technology Basic Plan 1996 are also committed to increasing government R&D funding and to building a national consensus on the priority of S&T (Science and Technology Agency, 1998).

Accompanying this, the industry is also taking a more strategic approach to the creation and dissemination of S&T knowledge. During the past two decades, due to globalization, the increased international competition, a faster pace of technological development and the downsizing of firms to core competencies, companies have become more receptive to external sources of innovation. An innovation gap has emerged from the shortening of the R&D timescale and the resources available to firms, and from the increase in competencies and technological inputs necessary to accomplish innovation. This innovation gap opens up between individual firms, attending to their short term needs for product development and longer term research, which is often located in university and government laboratories and has the potential to improve existing products incrementally as well as to create future products and processes. Therefore the necessity to combine external with internal sources of innovation has revised the role of industrial laboratory within firms, reducing both their scale and scope (Rosenbloom and Spencer, 1996). For some, this means carrying out in-house research, while for others, this involves “outsourcing” research via joint activities with research centres or universities (Delanty, 2001).

As observed in Gibbons et. al (2001), the industry’s role in research is no longer subordinate to the state. As the industry itself is subjected to contextualization, “peripheral” industrial research processes, such as health and safety, can no longer be separated from their more “core” industrial research processes, resulting in scientific expertise and state apparatuses co-evolving. Combined with the dynamics of international competition, the industry has been forced to expand and carry its innovation process into the heartland of knowledge production, becoming highly involved with the development of national programmes. Industrial leaders today are prominent members of research councils and programme steering groups. They work together with the government to ensure a better fit between scientific programmes and national (and corporate) economic objectives.

Moreover, increasingly, the creation of S&T knowledge is also done through linkages with the university. In the past, industry’s relationship with the university was that the university would be a provider of human capital, and, secondarily, a source of useful knowledge provider to the firm. In this view, what the industry needs and wants from academic researchers is just basic research knowledge (Etzkowitz, 1998). Today however, the university is increasingly being leveraged in the drive for S&T innovations. The university is seen to have comparative advantage in this area due to its research base and the fact that the knowledge base in the university is continuously being developed because there is a constant stream of students on the higher education side (Etzkowtiz, 1986). Given the importance and rapid pace of innovation, traditional forms of academia-industrial relations, such as consulting and liaison programs, have taken on a more intensive, formal institutional ties such as the setting up of firms and centres. That is, the increase of such interactions among the institutions has had the effect of generating new structures within each of them and the creation of integrating mechanisms. Previously, the various players worked in hierarchical systems, with predefined roles or on markets which forced rules on them. Now they are expected to assume multiple roles and functions, not only within their own institutions, but within their interacting partners. This not only creates a new overlay of interaction between the two actors but also new opportunities in the creation and dissemination of new knowledge.

Moreover, Etzkowtiz and Leydesdorff (2001) argue that individuals involved may even adopt a "network perspective", which can be broader than the sum of the participating groups; generating a new dynamic interaction. As the actors communicate, one expects differences in perspectives, leading to creative interactions in which the participants can transcend the ideas of their respective organizations to take a network perspective (Etzkowtiz and Leydesdorff, 1999). For example, at times, actors may take on the role of the other, such as the industry taking on the role of the university in developing training and research; adding a reflexive dimension to the overlay of communications.

Clearly then, there is a double layered system of variation and selection in terms of both institutions and functions, indicating that the agencies involved are able to use the knowledge base to change their role, interactions and positions. As Nowotny et al (2001) observe, knowledge creation can be considered as a necessary, but not sufficient step to innovation. Instead, knowledge creation "creates a potential which can be actualized by bringing together users, producers, entrepreneur, and policy makers in a 'transaction space' where problems and possibilities can be argued and traded off" (p.17). That is, innovation is based on knowledge flowing and recombining across the network interfaces (Kline & Rosenberg, 1986), leading to Etzkowitz and Leydesdorff (1999) to state that the communication patterns governing the creation and dissemination of knowledge in the networks are not expected to remain stable, and should be seen instead as evolving networks of communication. (Etzkowtiz and Leydesdorff, 1999).

1.3.2. Research and Development and High Tech Entrepreneurship

The Application (use) of S&T Knowledge

The economic benefits of network dissemination and expanding knowledge base are only realised when they are adopted and used by the labour force to produce goods and services; in other words to commodify knowledge. This is made even more critical when taking into consideration the constant stream of technological advances into a KBE, which compresses product cycles and speeds up the depreciation of human knowledge. Furthermore applying knowledge would help generate feedback to the knowledge creators and jumpstart the next round of innovation.

The implication of this is that there is a need to nurture R&D and high tech entrepreneurship. Furthermore, the roles of multinational and local small and medium enterprises would play a key role in this area.

The Role of Multinational Companies (MNCs)

Increasingly today, due to rising costs and risks of new technology developments, MNCs are moving towards widespread cross border mergers, acquisitions and alliances. Data from the OECD *Science, Technology and Industry Scoreboard 2003* reflects this trend, with an increasing share of technology being owned by firms that do not come from the inventors' country. In the mid-1990s, an average of 14% of all inventions in any OECD country were owned or co-owned by a foreign resident. Furthermore, by the late 1990s, about 6% of patents of OECD residents were the result of international collaborative research.

Despite this, Freeman and Hagedoom (1995) argues that factors like the unstructured and intangible nature of R&D information with personal interactions, the need to protect product development and key issues in corporate strategy from the competition would discourage MNCs from dispersing their R&D activities. Therefore even though industry R&D expenditure may be increasing, the share of this expenditure by MNCs may not be high or is most likely to be following a downward trend (See Table 7.).

Table 7: Proportion of industrial R&D expenditure finance from foreign sources by selected countries, 1992-1996. (In Percentages).

	Canada	Germany	U.S	Italy
1992	-	2.5	9.0	5.4
1993	17.2	1.9	9.6	5.9
1994	17.0	2.0	10.6	8.1
1995	-	1.9	11.3	5.4
1996	17.0	1.9	-	5.4

Source: National Science Foundation, *Science and Engineering Indicators*, 1996.

Local R&D and Entrepreneurship

Due to this, there is an increasing emphasis on the nurturing of indigenous R&D and high tech entrepreneurship. Instead of just supporting R&D at the local universities and PRICs, support is also increasingly growing for the local private sector take on R&D. This often takes place in the form of start up firms. Start up firms are an important source of innovation and even have an advantage over large established firms in emerging areas where demand patterns are unclear, risks are large, and the technology base has yet to be worked out.

The emphasis on innovation or more specifically the need to sustain continuous innovation has placed enormous stress on the traditional organizational structures of business firms. As knowledge loses its value quickly, there has been a dismantling of internal hierarchies, what Suarez-Villa (2003) observes as the "deconstruction of the firm", to facilitate the sort of interaction and cross functional action to sustain continuous innovation. This flattening of hierarchy also involves the dismantling of lines of authority and control to encourage autonomous initiative by those who are most likely to come up with new discoveries leading to spin off firms, and more efficient interactions with other actors. In other words, the dismantling of the industry's internal research capabilities has led to the focus on entrepreneurship, such as the "spinning off" of entirely new firms that can be more effective at facilitating innovation and enhancing the innovative capacity of firms. Spin off firms can connect to external networks that can provide new ideas, knowledge and methods (Suarez-Villa, 2003). Microsoft is a notable example of a firm that began life as a start up. In the United States, even large firms such as Cisco are going about buying or buying up shares in small innovative firms because these would help spark further growth for the company (OECD, 2000).

Central to the support of start up firms are the presence of an aggressive venture capitalist industry and a sufficient supply of educated manpower. The US, currently leads the world in high tech start ups. Its Silicon Valley model of high tech developments consist of a dynamic segment of small medium enterprises (SMEs), an aggressive venture capitalist industry and an excellent functioning staff market. This model has contributed to US leadership in microelectronic, computer technology, biotechnology and IT, among others (Hu amd Jang-sup, 2002), and is in turn now increasingly being adopted by other economies. Therefore, S&T policies would have to be expanded to include initiatives that would help the promotion of entrepreneurship.

In summary, the blurring boundaries between science and technology have lead to the creation and dissemination of S&T knowledge by the government and the university to take on a strategic stance. In order to ensure optimal creation and dissemination of knowledge, manpower development, linkages with the university and industry and support of R&D have stepped up. From the industry, the creation of an innovation gap has spurred the formation of a closer and strategic alliance between the industry and the state, and the industry with the university. Meanwhile, local R&D and entrepreneurship are being promoted to ensure the continuous cycle of creation and dissemination of knowledge. Clearly then, the two-way flow of *Endless Frontier* between industry and universities and PRICs can no longer apply; instead an *Endless Transition* would be a better description to the new pattern of creation, dissemination and use of S&T knowledge.

In terms of the S&T knowledge infrastructure in a KBE, it is being built by networks among key actors such as industries, academia, and governments. These actors are interlinked as institutions in a network which then creates the resulting knowledge base. The latter can be considered as a "system of communications on top of the institutional carriers" (Leydesdorff and Scharnhorst, 2003, p. 7). While the institutional networks integrate, the communication systems can be expected to change in terms of functions. With strategic know how and competence being shared interactively, participants and observers can specify further changes, by proposing and codifying new combinations. These reconstructed codifications would in turn differentiate the network base further (Leydesdorff and Scharnhorst, 2003).

Despite this dynamism, trajectories are still formed by chance processes at interfaces when technologies are "locked-in" within industries. [14] These stabilizations and trajectories however are not expected to last. For example, due to globalization, local niches may be dissolved as new horizons offer a variety of other options. Moreover, the different weights of relations in a network can change with the non-stop processes of appropriation, partnerships and competition, and these new balances and imbalances can be expected to provide a feedback in the knowledge infrastructure at other ends. The new (sub) systems can then be further expected to recombine into new solutions with different levels of success. Eventually, the actors involved can be expected to continuously compete in an uphill search

[14] Firms often network so as to develop the *de facto* technological standards in the formative periods of new technologies. A very good example of this would be the development of the GSM standard, which is now the common standard for the use of mobile phones in Europe. For another example, like the QWERTY standard keyboard, see David (1975).

for new stabilizations and solutions (Kauffman, 1993; Frenken, 2000).

CHAPTER TWO

THEORTICAL FRAMEWORK AND METHODOLOGY

Chapter Two: Theoretical Framework and Methodology

2.1. Introduction

The reconfiguring forces in the *endless transition* of knowledge intensive economies discussed in the previous chapter, indicates that innovation can be defined at different levels and from different perspectives. In order to examine this, I will be looking at two closely related models of innovation, the national innovation system (NIS) and the triple helix model as part of the theoretical framework. Both models are useful because they are based on the assumption of a non-linear model of innovation and examine the structure and configuration of innovation within a country.

Guided by this theoretical framework, my methodology would involve historical research as well in-depth interviews with the relevant personnel. This would support the observations suggested in the theoretical framework and provide further avenues for discussion.

2.2. The Theoretical Framework

2.2.2. From National Innovation Systems (NIS) to the Triple Helix Model

The concept of a NIS[15] has been commonly used to identify the set of public institutions and private organisations within a nation state that jointly develop the nation's S&T resources and are deployed in the nation's economic production system. In this approach, instead of examining the number of the innovative products and processes that has been introduced, a broader analysis that focuses on the "network of institutions in

[15] The basis of this model stemmed from Friedrich List's conception of "The National System of Political Economy (1841).

the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987, p.1) is adopted. Therefore, the actors and their interactions define and determine the innovation performance.

Despite the popularity of this concept and its wide usage[16], there are a number of inadequacies in this NIS concept. For one, there seems to be no agreed definition of what the key structural elements of a NIS are, and how these elements must interact to determine the overall performance and pace of innovative activities in a country. Studies using the NIS to carry out national or comparative studies[17] generally reveal and provide different public policy perspectives that can help spur technological innovation. In other words, the NIS in different countries would differ depending on the characteristics and condition of the country.

This means that the unstructured nature of NIS would make it difficult to model and replicate successful innovation systems. Even if some key characteristics can be modelled or transferred, they often require a substantial effort as well as considerable time for them to be replicated successfully (David, 1975 and Arthur, 1989). Therefore, the NIS approach offers only a limited understanding of the dynamic properties of innovation systems, especially with regard to their stability and evolution (Balzat and Hanusch, 2003). There is a need therefore to study these elements, so that the NIS model would be more aligned to its theoretical foundation of evolutionary economics[18], where it is important to consider qualitative change such that dynamic processes lay at the centre of attention. One model that does this is the triple helix model.

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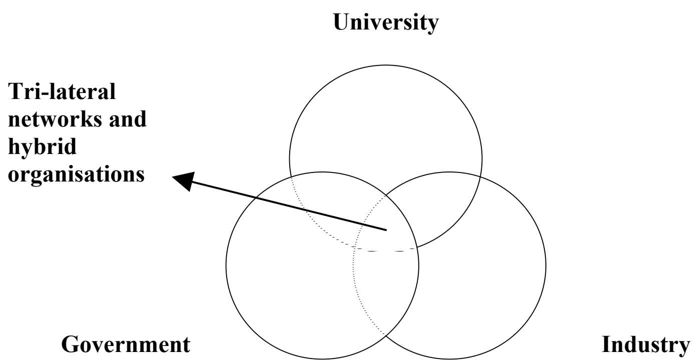
[16] See Dosi et. al. (1988) and Freeman (1987)
[17] See Patel and Pavitt (1994) and Nelson (1993).
[18] Saviotti (1997) and McKelvey (1997) explain how evolutionary economics actually constitutes the foundation of NIS.

The nonlinear model of innovation extends upon the linear model by taking into account the interactive and recursive interactions. That is, the nonlinear term is expected to change the causal relations between input and output. The innovator can now be changed by its innovation; one can be the observer and the participant, who can then be expected to change the innovation. Sometimes, these selections may "lock-in" upon each other for a while, whereby then the next order selections, like how the actors react to it, become important, resulting in a continuously evolving innovation system. For this, the unit of operation and analysis ought to be the communication patterns among the main actors (Leydesdorff, 1997).

The Triple Helix model of university-industry and government examines this. It adopts an evolutionary approach where initially it was very much similar to the NIS, in the sense that the state or industry will play a major role. However, in its current phase, where the infrastructure of the KBE implies an endless transition, it recognizes that interactions between the university-industry-government are reciprocal and recursive. For example, transformations in the different actor's spheres will take place as a result of more integrated relationships between them as well as their reflexive take on such relationships. Each of these spheres has a distinct purpose separated from the others but they also take on the role of the other. For example, the new arrangements in communication patterns have opened up the possibility that universities can become, at least in part financially self supporting institutions; entities obtaining revenues through licensing arrangements for the industrial use of knowledge, in other words taking on an entrepreneurial role. This allows the possibility of it becoming a key engine for economic growth. Furthermore, what were once bilateral relations between government and university and between industry and university are now evolving in the direction of a triple set of links: tri-lateral networks and hybrid organizations (See Figure 1.)

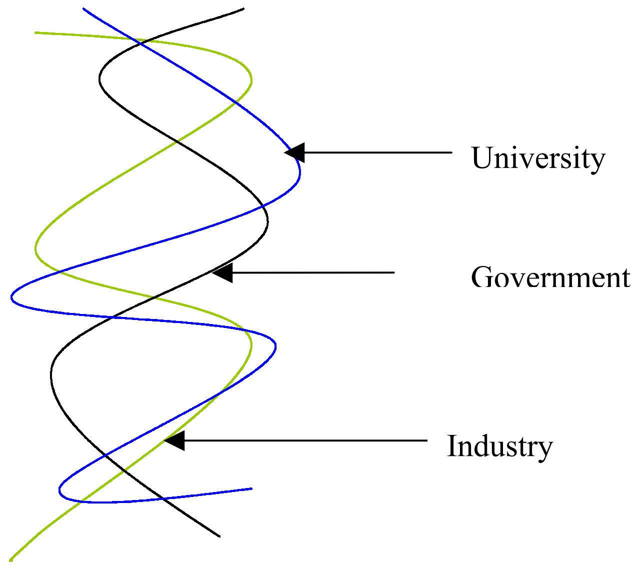
Figure 1: The overlapping roles between the actors and the creation of tri-lateral networks and hybrid organizations.



Source: Etzkowitz and Leydesdorff (1999)

Therefore, the existing network of relations can generate a reflexive sub dynamics of strategies and projects that creates surplus value by continuously reorganizing and harmonizing the underlying infrastructure, such that there is at least an approximation of the goals of each actor. Each strand in the triple helix configuration can relate to the other two, and in doing so, create an emerging overlay of communications, organisations and networks among the helix. These interlays would never lead to a complete compromise; in other words, university-industry-government relations should always be understood as evolving networks of communication (Etzkowitz and Leydesdorff, 1999). (See Figure 2.)

Figure 2: Evolving networks of communication between actors in the Triple Helix Model



Source: Etzkowitz and Leydesdorff (1999).

In this sense, the triple helix model transcends previous models of institutional relationships, in which either the economy or polity predominated, with the knowledge sector playing a subsidiary role. Instead, the triple helix model attempts to look at the dynamic and new configurations of various institutional forces emerging from innovation systems, leading to the new re-alignment of primary roles in the system. For that, Etzkowitz and Leydesdorff (1999) state that the Triple Helix model will undergo four main processes. They are:

- Internal transformation in each of the helix.
- Transformation of each helix brought about by influence of one institutional sphere upon each other.
- The creation of a new overlay of trilateral linkages, networks, and organizations among the three helices, serving to institutionalize and

reproduce interface as well as stimulate organizational creativity and regional cohesiveness.

- The recursive effect of these inter-institutional networks, representing academia, industry and government, both on the helix in which they emerged and in the wider society.

The triple helix model is also useful because it overcomes the “national” element of NIS. The relevancy of this element has been increasingly reduced by international economic integration, where national determinants of innovative activities are increasingly removed at the expense of international conditions. That is, the process of globalization may be increasingly making the importance of “national” redundant. However there are others like Michael Porter (1990) who argues that the role of the nation may even be more enhanced now because “competitive advantage is created and sustained though a highly localized process” (p.19). With fewer impediments, the nation has taken on a growing importance as it is now the source of skills and technology that underpin competitive advantage.

The triple helix model on the other hand shifts away from this contentious element. Instead, it is the university that will play an enhanced role. Instead of being just a manpower provider, the increasingly close links between government, industry and university, have seen the university undergoing a “second academic revolution” (Etzkowtiz, Sculer and Gulbrandsen, 2000 and Etzkowtiz et al. 2000). Universities are now taking on an “entrepreneurial” turn in which they take advantage of their knowledge base by commercializing their knowledge and become an incubator for new firms.

2.2. Entrepreneurial University Transformations.

According to Etzkowtiz, et. al. (2000), the entrepreneurial university will evolve in these four processes:

1. Internal Transformation of the University Helix

As the university expands its role in innovation, it would have to revise its existing tasks, functions and roles. These should be reinterpreted and expanded in response to new goals. Over time, the university will then reformulate its mission to take into account the entrepreneurial paradigm.

2. Trans-institutional impact between the three helices.

Formats for collaborative arrangements should be institutionalized in legal and customary arrangements and such arrangements should take on a flexible form.

3. Interface processes within the University helix.

The entrepreneurial university would have an expanded capacity for intelligence monitoring and negotiation with other institutional spheres. Therefore centralized or decentralized interface capabilities for such activities will be spread throughout the university.

4. Recursive Effects

Besides just establishing links with the government and industries, the university also develops capabilities to assist the creation of new organizations. This will lead to the formation of trilateral organizations, with new cross-organizational and cross-institutional features.

2.3. Methodology

In Singapore, there are two main public universities, namely the Nanyang Technological University (NTU) and the National University of Singapore (NUS). I have chosen NUS as the model to study for the emergence of the entrepreneurial university because NUS has a long and well established tradition for R&D in the field of S&T.

NUS's transformations towards an entrepreneurial role will be supported by historical research and interviews with the relevant personnel from NUS will further substantiate these observations. Additionally, interviews were held with the government to provide greater avenues for the appreciation and reflection of these changes. In the event that interviews were not granted, extracts from newspapers and press releases will be used.

In total, six interviews were carried out, with two via emails and the remaining via face to face contact. Extracts of the interviews will be used and inserted throughout the chapter when deemed relevant.

CHAPTER THREE

THE EMERGENCE OF THE ENTREPRENEURIAL UNIVERSITY

Chapter Three: The Emergence of the Entrepreneurial University.

3.1. Academic Transformations in the University.

The emergence of the triple helix model of institutional alliances has led to the university undergoing various transformations, especially to the extent of being entrepreneurial. This chapter looks at some of the major changes that the university has undergone as it shifts to a new role in the knowledge based economy.

According to Manuel Castells (1994), the most basic function of the university has always been to teach. The ideological apparatus role that universities took on initially, as demonstrated by the European tradition of church based universities, had actually helped to train church bureaucrats. This was similar for the traditional Chinese, Japanese and Korean university system, which was structured around the training of bureaucrats. At the same time, the university was also a mechanism for the selection of dominant elites, including such mechanisms such as the socialization process of the elites and the formation of the networks for their cohesion. The English system, built around the dominance of Oxford and Cambridge universities is, most likely the quintessence of the elitist role of the university. More recently, however, the process of industrialization has expanded this function, such that the universities are now required to train, in mass, engineers, accountants, economists and other professional workers. Simply put, the function of the university is to serve public goals and more importantly is a welfare organization, depending on state funding (Melody, 1997).

The university however started, to undergo its first academic revolution in the late 19th century, taking on a research role in addition to its teaching role (Jencks and

Riesman, 1968). Research polytechnics/universities have long been present in Germany[19], but the research oriented universities only started gaining momentum after its success[20] in the US. The shift to this role was grounded in economic considerations.

According to Melody (1997), the late 19th century witnessed the beginning of a reform of the welfare institutions. Michael Power (1997) termed this as the arrival of the audit society, because there was the emergence of a new demand for accountability in the public sector for industrialized countries (Peters, 1992; Woolgar, 1997). Like any other major public institution, the university was asked to justify its public service performance, its demands for public resources, and the efficiency of its management of resources. In the European universities, the accountability issue has driven the introduction of national systems of external evaluation of universities and in countries such as Britain, a consequent ranking and funding of institutions.

Along with this was a marked decline in state funding for universities. According to Cohen et. al. (1998), in the US, decline in federal funding per full time academic dropped by 9.4% in real terms between 1979 and 1991. This was somewhat offset by industrial funding, which was boosted by the Economic Recovery Tax Act of 1980, which extended industrial R&D tax breaks to support research at the university. Furthermore, this funding took on a strategic element. Instead of just providing funding

[19] There are a number of different strands of research universities that were established before 1850. England had the *Royal Institution of London* that served as a center for both basic and applied scientific laboratory work. France, under Napoleon, developed *Ecoles* that was designed to secure strength and capacity via research for empire building. The German research universities grew up as institutions with strong theoretical and empirical work in the sciences and this strand of university was subsequently modeled and set up successfully in the United States. Examples of this would include the John Hopkins University and the University of Chicago.

[20] See Etzkowitz (2002).

equally, state funding became allocated more on the basis of strategic research work carried out by the universities (Jacob, 2000b).

For this, universities started turning to research, paying careful attention to practical objectives so as to gain more funding. Etzkowtiz et. al. (2000) termed this as the *first academic revolution*, which created a research tradition and a cadre of research teams, for universities to embark on its later, *second academic revolution* (See Figure. 5). In the US, the Morrill Act of 1862 helped to set up the necessary legislative framework for tying up universities to agricultural research by the state and industry. This act, followed by the Hatch Act in 1887, helped to create the agricultural schools of California and Wisconsin, or the engineering schools at Michigan and Illinois, generating a culture of close interaction between the university and the business world. Moreover, this was further expanded to non-agricultural areas ranging from engineering to chemistry, as US universities pursued extensive research collaboration with the industry (Rosenberg and Nelson, 1994). For example, the academic discipline of chemical engineering was largely developed through collaborations between US petroleum and chemical firms and *Massachusetts Institute of Technology* (MIT) (Rosenberg, 1998). The research university received a further boost during the Second World War and Cold War, where the military needs of the government led to the transformation of U.S. universities into major research performers.

By 1995, universities' share of total U.S. research and development (R&D) performance was 16% as compared to 7.4% in 1960 and the universities accounted for more than 61% of research performed within the U.S. in 1995 (National Science Foundation, 1996). Research universities were also increasingly being established, buoyed by the success of research schools like *Stanford*, MIT and *California Institute of Technology* (CalTech). These universities played a fundamental role in generating new knowledge and using it to promote economic growth in their respective regions (Etzkowtiz, 2002).

This shift however brought about complications for the university. Universities were now increasingly forced to operate like businesses, competing with each other for students, the best professors and their share of the state's diminishing budget. These developments are further seen in the internal organization of the university. Departments and faculties are increasingly becoming administrative units rather than being based on the traditional disciplines. The blurring of the traditional boundaries is not a result of a greater multidisciplinary but because of the imposition of audit cultures in the university (Rothblatt, 1997). Departments are under pressure to generate funding for research and funded research is prized above individual research.

In the US, although federal investment in academic R&D actually increased during the 1990s, academic researchers perceived a shortfall of resources during this period (National Science Foundation, 1996). The ability to conduct advanced research has become more widespread, and this diffusion of research to a broader range of universities created the paradox [21] in which even as research funding increases, competition for such funds also increase, making it more difficult to obtain funds. Combined with this has been the increasing scale and costliness of research. With the

[21] The explanation of this paradox, according to Etzkowitz (1999), lays in the expansionary dynamic inherent in an academic research structure, based upon a Ph.D training system that produces research as a by product, and is driven by the ever increasing number of professors and their universities who wish them to engage in research. Formerly this process was largely impelled by the wish to conform to the prevailing academic prestige mode associated with basic research. In recent years however, this expansionary pressure has intensified awareness of the economic outcomes of basic research, drawing less intensive areas of the country into competition to expand the research efforts of local universities as an economic development strategy.

notable exception of a relatively brief wartime and early post-war era, characterized by rapidly expanding public resources for academic research, universities in US have always lived with the state of resource scarcity. As funds become increasingly insufficient, universities begin to undergo a "second academic revolution" (Etzkowtiz et. al., 2000); that is to take on an entrepreneurial role (See Table 8.).

Table 8: Expansion of the university's role and mission.

Period/ Role and Mission	University before Revolution	First Academic Revolution	Second Academic Revolution
Role	1. Teaching	1. Teaching 2. Research	1. Teaching 2. Research 3. Entrepreneurial
Mission	1. Preservation and spread of knowledge	1. Preservation and spread of knowledge 2. Gathering funds for the university via research capabilities and the production of knowledge.	1. Preservation and spread of knowledge 2. Gathering funds for the university via research capabilities 3. Economic development.

Source: Etzkowitz et. al.. (2000).

3.2. The Entrepreneurial University.

During the past two decades, a broad range of universities, both public and private, have established a number of mechanisms to take advantage of their research foundation, and in the process increasingly embrace the entrepreneurial function. The following section highlights the various key features that universities have generally adopted to take on an entrepreneurial function.

3.2.1. Entrepreneurial Science and the Entrepreneurial Scientist

Entrepreneurial activities of scientists are by no means a totally new phenomenon. Such things occurred in 19th century German pharmaceutical science and the trend of industrial consulting by scientists actually started in the late 19th century at Harvard and MIT, although they were relatively few at that time (Shimshoni, 1970).

The advance of ICT however has expanded the potentiality for commercializable results in the process of academic research. Basic research can now produce results even without the direction of scientists or universities requiring their disclosure; providing an immense amount of opportunities for the commercial exploitation of science; a phenomenon that Etzkowtiz (1999) terms as the emergence of "entrepreneurial science" (p. 211).

It is the research scientists, whom typically carry out research at the frontiers of science that are now in the best positions to utilizing these opportunities of entrepreneurial science. Interestingly and increasingly, these scientists are taking advantage of the situation by and for themselves, rather than leaving them to others They have created academic spin off firms and commodified their research via intellectual property rights and are using these rights as a bargaining chip for more research funding especially from the private sector. In the US, this was further encouraged by the Patent and Trademark laws Amendment Act of 1980, more popularly known as the Bayh-Doyle Act, which permits universities, small businesses and non profit institutions to hold exclusive patent rights to the results of research sponsored by the federal government. Further driving this trend is the recent scientific advances in molecular biology and polymers that could be quickly developed as sources for profit and the dearth in funding.

Etzkowitz (1998) demonstrates evidence of this academic entrepreneur in his study of the cognitive effects of new industry-university linkages at the State University of New York, Stony Brook. A scientist was cited by him as saying that his goal is "… to not only run a successful company … [but also to] start a centre [at the university] that would become internationally recognized...", and yet continuing to retain their traditional role as "individual investigator", directing a research group (p. 827).

Therefore the term "academic entrepreneur", may be used to describe an academic who starts a firm to commercialize her research as well as the senior researcher who is good at wiggling sizeable research grants and as a result become a de facto employer of large numbers of post-doctoral and other junior researchers (Hellsmark, Jacob and Lundqvist, 2003).

3.2.2. Technology Transfer Infrastructure

The impact of the entrepreneurial activities of the scientists can be observed in the changing technology transfer infrastructure of the university. In the past, technology transfer from the university to the industry took place simply via consulting or liaison programs. However, as research scientists begin to commodify their research, units such as technology transfer offices were created at the universities. These offices often deal with the development of IPRs; assisting in the protecting and commodification of knowledge, and also knowledge transfer; they actively seek out interested industry players who would want to license the patented information[22].

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[22] For example, at the University of Twente in the Netherlands, with state funding on decline, a "Transferpunt" office was set up in 1979 to explore new ways to link up with the industry and increase third stream income. See Maassen and Van Buchem (1990) for further explanation.

In addition, to further reach out to the industry, more interdisciplinary project oriented research centres have been set up. Academic departments based on traditional disciplinary fields of knowledge will continue to be important, but they now cannot do all the things that the university needs to do. For this outward reaching research centres that express nondisciplinary or interdisciplinary solutions to problems will bring the university closer to the industry who are seeking to profit or take up opportunities that research in S&T brings (Clarke, 1998).

3.3.3. Academic Spin offs and the Industrial Penumbra around the University

Other than just making commercializable results available for sale to existing firms, faculty members are also forming firms. This is because knowledge commodities like software must be maintained, enhanced, and translated to different platforms to be useful. These activities require organizational and financial resources that are often well beyond the capacity of an academic laboratory and its traditional research funding sources, especially if the demand is great and the software complex. Therefore if the interest in the software is not only from academic labs but from companies who can afford to pay large sums, the possibilities open up for the building of a company around a program or a group of programs and making them available to the industry at commercial rates while distributing to academia at a nominal cost (Etzkowitz, 1999).

In a study carried out by Etzkowtiz (1999) on the impetus to firm formation at *Stanford University*, researchers highlighted their dilemma of success; that despite their initial success at research, they faced problems when it came to expanding their program. One researcher was quoted saying, “We had an NSF [National Science Foundation] grant that supported [our research] and many people wanted us to convert our program…but we couldn't get [further] support… [furthermore when we] looked for companies that might license it from us, none were really prompted to maintain or develop the software further" (p. 220). For this, academics enter into joint agreements with the industry. They learn to balance academic and commercial values. There is a compromise between the two sides, meeting academic and business objectives at the same time, through the support of a government research to partially subsidize academic access to the firm's product. Studies have shown that a significant number of new technology based businesses in both the United States and Western Europe have been established by scientists emerging from academia based institutions (Jones-Evans, 2000).

In addition, universities today are also increasingly providing incubator facilities. Academic incubators offer officer support services, access to university facilities, such as libraries, specialized scientific equipment as well as access to capital, business plan assistance, mentors and assistance when the start up company is ready to graduate from the incubator programme (Rice and Matthews, 1995). Indeed, other than venture capitalists, universities today are increasingly interested in working with venture capitalist backed, academic spin-offs so that they can commercialise early stage research and produce greatest return for the institution. For example, at *Twente University*, there is a three stage organizational flow in the formation and continuation of new enterprises, under its Temporary Entrepreneurial Placements (TOP) program. In the first phase, firms supported by TOP reside for a year in the university. Firms that survive this first stage would then take up residence in the Business and Technology Center (BTC), an incubator centre, that is supported by firms and local government. Then when time and growth dictates, this firm can move to the *Twente Business and Science Park*, that has *Ericsson*, a giant Swedish telecommunication firm as an anchor tenant that is adjacent to the campus and the centre (Clarke, 1998). In the UK, universities have also assisted in the setting up of these companies and often spend considerable management time on such negotiations. According to the Department of Trade and Industry, statistics in the UK, based on finding from 80 universities, 46 of them have a wholly, partially owned subsidiary for exploiting research and technology.

In addition, the existence of previous generation of university originated start-ups provides consulting opportunities, even for faculty at other area universities, creating future entrepreneurial activities. From their contact with these new companies, faculty become more knowledgeable about the firm formation process and thus become more involved themselves. Faculty who have started their own firms also become advisors to those newly embarking on a venture. The availability of such role models hence makes it more likely that the other faculty members will form firms out of their research results, when the opportunity arises.

Clearly the university is a hotbed for the creation of new firms and this has resulted in the creation of an industrial penumbra around the university. Examples of this industrial penumbra can be found at the Silicon Valley in the United States. Two of the best engineering and science universities in the country, *Stanford University* and the *University of California at Berkeley*, are located within 50 miles of the 3000 plus high technology enterprises in the Valley. The majority of these are spin offs from the universities because these two universities are research universities where engineering and science training is closely linked to the industry. Firms that located themselves in the valley, did so to have easy access to hiring Stanford trained engineers and to keep in close touch with research at the university. The firms' themselves also engaged in continuous training by sending their engineers "back to school" in Stanford and Berkeley. Stanford and Berkeley's business schools also trained young managers well versed in particular problems in the high technology industries. As such, high technology companies and entrepreneurs often establish their businesses near universities to benefit in various ways from their creativity and technological output (Etzkowitz, 2002).

3.3.4. Industrial Penumbra in the University.

The creation of a penumbra of companies surrounding the university has in turn also given rise to an industrial pull on faculty members. Increasingly, an academic entrepreneurial culture is growing within the university. This culture encourages scientists to look at their research from two different perspectives; firstly, a traditional research perspective in which scientists determine if research can be published; furthering their credibility. Secondly, an entrepreneurial perspective in which results are examined for their commercial and intellectual opportunities (Latour and Woolgar, 1979). Indeed, the mindsets of scientists today are increasingly shifting towards the second perspective. A faculty member at Stanford states that, "It is… motivating for us to try to identify things that may be licensable or patentable… because according to University policy, 30 percent of the money goes back to the scientist, 30 percent goes back to the Department… so almost all the computing equipment and money for my post docs have been funded by the work we do" (as cited in Etzkowitz, 1999).

This culture is also pervasive at the macro level, where the administration and organization of the university increasingly resembles a corporate organization. As Sutz (1997) argues,

> In former times, the university did not carry out the functions that are characteristic of the firm or enterprise; it did not market its capabilities … In the old days, the transfer of the knowledge produced by the university to its end-users took place through intermediate agents… Nowadays, the university has become a direct producer of goods and services for end-users… the rules of the game that used to apply outside academia have become the standard in university facilities to (p.11).

This change was clearly seen in a study of universities taking on an entrepreneurial role in Australia by Considine and Marginson (2000). They observe that university administration has undergone key crucial changes that include;

- University purpose is now being defined by forms of strong executive control.
- University missions and governing bodies start to take on a distinctly corporate character, where market mediates much of the relationship with the world outside and performance targets are superimposed on scholarly honorifics.
- The education of international students would be driven by commercial and entrepreneurial spirit.

Similarly, Hellsmark, Jacob and Lundqvist (2003) also observe that in the *Chalmers University in Gothenburg*, which is taking on an entrepreneurial function, they package “entrepreneurship as a product” (p. 1556). They observe that deans and heads of departments are coming more to resemble managers than academic heads, trained to foster entrepreneurship. That is, there would be courses in entrepreneurship and restructuring of the organizational structure of the universities to allow for the active promotion of entrepreneurship among students and faculty. This follows from the contemporary understanding of entrepreneurship, which is a skill that can be increasingly taught. As such, modules teaching entrepreneurship have been launched and seminars and information regarding how the university can assist in setting up businesses are increasingly being held and circulated.

At the same time, there was also a change in the academic labour market. Previously this labour market had been fairly stable, but now the current situation is radically different. Universities are looking to attract top research talent or entrepreneurial scientists. As such, academics in the top end of their careers are now being encouraged to engage in the game of looking for the best deal rather than sticking to a particular university.

For this, academic led innovation has been noticeable especially in places such as MIT and *Chalmers University*. One study found that 636 MIT alumni founded companies in Massachusetts, and these companies account for a third of the Massachusetts economy. The *Chalmers University* is also distinctive for making innovation a particular specialiality, generating approximately 40-50 companies a year and a thousand of jobs (Hellsmark, Jacob and Lundqvist, 2003).

3.3.5. The University as an Engine of Economic Growth

The success of academic has led to innovations in technology based regions like Silicon Valley and the Route 128 region surrounding Boston and Cambridge[23] have led to business leaders, policy makers and academics to conclude that the university plays a fundamental role in developing technological innovations and technologies that power the economic growth of the region. For this, increasingly, more specific and explicit strategy of using the university as an engine for growth has been adopted (Feller, 1986).

[23] Further information can be found in Saxenian AnnaLee (2000) and Lee *et. al*. (2000).

For example, the *State University of New York (SUNY) at Stony Brook* encouraged its molecular biology faculty to explore the practical implications of their research through seed research grants and incubator facilities. Similarly, the *Linkoping University* in Sweden has adopted the same strategy, first for information technology (IT) and than for medical schools. In Philadelphia, its older industrial area has been renewed by creating health care and pharmaceutical clusters via a base of 80 colleges and universities, 6 medical schools and 24 teaching hospitals (Etzkowitz, 1999). Niche formation for regional economic growth has clearly proven to be a successful local economic development strategy.

Clearly, "nowadays universities are more and more regarded by both enterprises and governments as institutions that are to be devoted to 'national good' of economic competitiveness rather then to the 'universal good' of knowledge" (Sutz, 1997, p.12). The perception of universities as merely institutions of higher learning is gradually changing; with the academic enterprise now "managing" its knowledge has hence transformed itself into leading role for economic growth in the knowledge based economy (Machlup, 1962).

Given the aforementioned, the definition of an entrepreneurial university that will inform this thesis is one that has a diversified funding base, an increasingly corporate organisation and wide ranging interface capabilities that will connect the university closely to the industry and actively promote entrepreneurship.

CHAPTER FOUR

ENROUTE TO A KNOWLEDGE BASED ECONOMY IN SINGAPORE

Chapter Four: *Enroute* to a Knowledge Based Economy in Singapore

4.1. Introduction

In this chapter, the discussion of the emerging triple helix model in a knowledge based economy is brought into the context of Singapore. In Singapore, as the drive for life sciences accelerates, the triple helix model becomes increasingly dynamic, with the university playing an enhanced role and more linkages being built between all three actors in the model. For this, a short introduction of Singapore would first be provided. Then, Singapore's shift towards a knowledge based economy will be examined in the arena of the creation, dissemination and application of S&T. As the government plays a key role in Singapore, the changing S&T policies will be used to examine the impact on the creation and dissemination of S&T knowledge. Following this, the application of S&T knowledge in terms of technopreneurship will be discussed. This chapter will conclude with an overall summary of the S&T knowledge infrastructure in Singapore's shift towards a KBE.

4.1.1. Introduction: Singapore

Located at the southern tip of the Malay Peninsula in Southeast Asia, Singapore is a diverse multi-ethnic society with a population of 4.16 million, in which 77% are Chinese, 14% Malays, 8% Indians and the remaining 1% are of the other ethnic groups. It has four official languages: English, Malay, Mandarin and Tamil, and Buddhism, Hinduism, Christianity and Islam are some of the major religions of this city state

(Singapore Department of Statistics, 2000). Singapore gained its independence in 1965 and has been ruled by the People's Action Party (PAP) ever since.

Singapore has the twin disadvantages of being small (Land area of 633 square kilometres) and devoid of natural resources. Nevertheless, the government carried out a well structured and phased economic modernization strategy that saw the country undergo rapid economic growth, with gross domestic product (GDP) at market prices at $164, 264.9 million in 2003 (Singapore Department of Statistics, 2003). Currently, Singapore is one of the most competitive economies in the world and also ranks as the 12th largest trading partner of the U.S. and the second largest investor in the U.S. (U.S. Chamber of Commerce, 2003).

4.2. The Creation and Dissemination of S&T Knowledge.

4.2.1. S&T Policy in Singapore's transition to a Knowledge Based Economy

Public policies have always played a significant role in the economic growth of Singapore over the last four decades. However, up until the late 1980s, much of public policy influence did not take the form of specific, clearly defined S&T policy instruments, but were often subsumed under more general economic policies and programs to help promote industrial growth and upgrading. This was clearly evident in the centrally directed strategies that was adopted and implemented to attract foreign direct investments (FDIs) and meet manpower needs in the 1960s and 1970s.

Nevertheless, as S&T became increasingly recognized as an important engine of growth in Singapore's shift towards a KBE, policies directed at building an indigenous S&T base intensified. Infrastructure supporting R&D expanded. Manpower development programmes to get people interested in R&D and the recruitment of foreign talent was implemented. More importantly, the academic component of the triple helix model, which comprises of NUS and NTU in Singapore, begin to be increasingly drawn into strategic R&D. Unlike the past, where the two universities focused on basic research, the government was now facilitating and encouraging a university-industry linkage. MNCs in turn, have been increasingly keen to not just be technology transfer bases but also to be partners with the universities as S&T become an endless frontier of opportunities.

These changing policies reflect a dynamic and evolving relationship between the industry, government and university. From the initial double helix relationship between industry and government, government and industry are slowly and more actively engaging the university to carry out R&D and innovation. A useful guide to mapping these evolving relationships with the university is Wong's (2003a) framework on the four distinctive phases that the innovation system in Singapore has gone through over the years. They include the industrial take off, the local process technological deepening, the R&D development and intensification phase, and the technopreneurial development phrases. These phases do not necessary follow a chronological order, especially the phase of technological development as it takes place almost concurrently with the R&D expansion phase. These phases will in turn be further categorized under the key functions of S&T; knowledge creation, dissemination and application, illustrating the changes with the emergence of a KBE.

The Industrial Take Off phase, 1965-1977

Owing to its natural limitations, Singapore, in its first industrialization phrase, adopted a strategy of being a labour intensive manufacturing export hub, driven primarily by foreign direct investments (FDI). But Singapore had virtually no S&T base. There were no technical institutes or engineering schools and this situation was further exacerbated by the departure of British expatriate engineers running the shipyards. For this, Singapore had to acquire technological knowledge from outside the country.

Initiatives under two broad categories of government policy helped to build up Singapore's S&T base from scratch, even though there were no explicit S&T policies at that time (Hu and Jan-sup, 2002). These two categories include;

1. The government actively promoting openness to international flows of capital, goods and labour.
2. The government investing heavily on technical education.

As part of promoting openness, institutions were created and restructured. The Economic Development Board (EDB) was reorganized in 1968, with an Investment Promotion Division being set up to help attract foreign investments, created industrial estates. The Jurong Town Corporation (JTC) was established in 1968 and managed the extension of the Jurong industrial estate and the creation of smaller estates in Kallang Park, Tanjong Rhu, Redhill and Tiong Bahru. At the same time, tax incentives were expanded and labour legislation such as the Employment Act and the Industrial Relations (Amendment) Act was passed in 1968 to promote industrial peace and discipline among the workforce. Support in the area of manpower development came via two routes. Firstly, local manufacturers were encouraged to enter joint ventures with foreign firms because they could supply the requisite managerial personnel, technical know how/skills and technology applications for the initial stages in establishing an industrial economy. Successful examples of these early joint government-industry technical training institutes include the Rollei-Government Training Centre and the Tata-Government Training Centre.

Secondly, the government also helped to enhance worker's capacity to assimilate and adapt foreign technology to local needs by investing heavily in technical education. A restructuring of the education system was initiated, with a bias towards technical education, to provide the requisite manpower for the industrial sector. In 1959 the Singapore Polytechnic abolished its general education, typing and stenography courses, focusing instead on craft, technical and professional courses in accountancy, architecture and building. In 1965, the University of Singapore agreed to award degrees to the Polytechnic's professional engineering, architecture and accountancy graduates. Subsequently, the Government decided that the Polytechnic should concentrate on technician training. All the professional courses of the Polytechnic were then transferred to the University of Singapore. As a result, the Engineering faculty expanded in 1969 and student enrolment subsequently expanded rising from 3,198 in 1969 to 7,546 in 1979. These efforts at providing technical manpower of various grades became an important "supply of skilled manpower required by industry at a critical time" (Soon, 1993, p. 26) and were crucial to the success of the policy of industrialization.

The initiatives were a success. The inflow of foreign direct investment (FDI) for manufacturing surged, with the value of foreign asset holdings in manufacturing holding increasing 24 fold between 1965 to 1976 (See Table 9.). Manufacturing also started to contribute increasingly to GDP and GDP growth ensued, reaching to around $16091 million in 1977 (See Table 10.). Employment figures also picked up, reaching around 903 thousand in 1977 (See Table 11.). By the 1970s, Singapore had three major clusters of industry, all dependent on imported inputs and export markets. These included a cluster centred on petroleum refining, another on shipbuilding and repair, and another on electronics.

Table 9: Foreign Investment in the Manufacturing Industry, in terms of Gross Fixed Assets, 1965 to 1975

Year	Total
1965	157
1966	239
1967	303
1968	454
1969	600
1970	1006
1971	1575
1972	2283
1973	2659
1974	3054
1975	3380

Source: Singapore, Economic Development Board, *Annual Review,* various issues.

Table 10: Gross Domestic Prices (GDP) figures at market prices by Industry, various years.

	1960		1970		1977	
Industry	$(Million)	(%)	$(Million)	(%)	$(Million)	(%)
Agriculture and Fishing	75.6	3.6	134.6	2.3	289.2	1.8
Mining and Quarrying	6.1	0.3	19.8	0.3	53.4	0.3
Manufacturing	249.6	11.9	1186.5	20.7	3980.1	24.7
Electricity, gas and water	49.8	2.4	149.1	2.6	308.6	1.9
Construction	72.5	3.5	397.0	6.9	1219.7	7.6
Commerce	719.3	34.4	1639.2	28.6	4328.0	26.9
Transport, storage and communications	292.3	14.0	629.8	11.0	2126.3	13.2
Finance, insurance, real estate and business services.	147.1	7.0	523.8	9.1	1542.3	9.6
Ownership of dwellings	100.0	4.8	292.0	5.1	688.8	4.3
Public administration and defence.	55.4	2.7	194.0	3.4	527.7	3.3
Community, social and personal services.	321.9	15.4	573.9	10.0	1227.3	7.6
Total	2148.6	100.0	5804.9	100.0	16,091.3	100.0

Sources: Singapore Department of Statistics, *various years.*

Table 11: Distribution of Employed Persons by Industry, 1965, 1970 and 1977.

	1957		1970		1977	
Industry	'000	(%)	'000	(%)	'000	(%)
Agriculture and Fishing	32.7	6.9	22.5	3.5	19.8	2.3
Mining and Quarrying	1.6	0.3	2.2	0.3	1.6	0.2
Manufacturing	67.4	14.3	143.1	22.0	245.5	27.2
Electricity, gas and water	4.0	0.9	7.6	1.2	11.4	1.3
Construction	24.6	5.2	43.1	6.6	42.0	4.6
Commerce	131.4	27.9	159.9	23.5	212.7	23.5
Transport, storage and communications	50.3	10.7	79.0	12.1	105.6	11.7
Finance, insurance, real estate and business services.	20.4	4.3	23.1	3.5	59.7	6.6
Community, social and personal services.	137.4	29.1	177.0	27.2	204.3	22.6
Activities not adequately defined	1.2	0.4	0.4	0.1	1.3	0.1
Total	471.9	100.0	650.9	100.0	903.9	100.0

Source: Cheng (1991)

With this initial process of industrializing, the government was actively engaging with the industry to establish Singapore's S&T base. Tangible resources are being built through the transfer of manufacturing technologies via FDI while the intangible resources are being built with the MNCs providing "learning by using" (Wong, 2003b, p.201) opportunities for manpower training. There are however no innovation linkages between the large MNCs and the rest of the economy and no supporting industries. Singapore's main source of advantage is the supply of abundant cheap labour as manufacturing and industrial productivity through low level technical skills were seen as the key to leapfrogging Singapore into the initial stages of industrialization.

Local Process technological Deepening Phase, 1978-1988

From the late 1970s, Singapore's competitive advantage in cheap labour began to be eroded by rising domestic labour costs and undercutting by other low cost economies in the region. As Hu and Jang-Sup (2002) observed the oil induced recession of 1975 had shown that the labour intensive, low value added industries that had powered Singapore's first decade of economic growth, were increasingly becoming incompatible with the constraints of a tight labour market, and further worsened with the industrial plans of neighbouring countries which premised on labour intensive industries (Hu and Jang-Sup, 2002). As a result, Singapore had to move beyond being a production to capital and knowledge intensive base.

To attract more high value added FDIs, the government initiated a three year wage correction policy from 1979 to 1981 to provide incentives for capital investment and productivity enhancement. Henceforth, more emphasis was placed on mechanization, automation and computerization. Capital equipment purchases, including purchases of imported equipment for productivity enhancement were incentivised and skills training centres were established to facilitate rapid learning.

Knowledge dissemination from MNCs to locals took the form of further joint government-industry training institutes that would train workers in supporting industries that catered to meeting MNC's needs. Knowledge dissemination also occurred between the MNCs and local firms, particularly with Local Industry Upgrading Programme, where a number of successful partnerships have also been formed, for example, Uraco and Amtek. The subsequent formation of the National Information Technology Plan (NITP) in 1985 and the National Automation Masterplan in 1988, targeted at promoting the diffusion and utilization of Information Technology (IT) and advanced manufacturing technologies also facilitated the local firms to play a more effective role.

Knowledge dissemination also occurred in tandem with the enhancement of the knowledge base of workers. Heavy investments were made in broad based technical and engineering training and education to upgrade the workforce. The government led the way with four key programmes during this period; the Civil Service Computerization Programme, Defence Modernization Programme, Automation Programme and the Civil Works Programme. These were significant because they enabled the deployment of state of the art capital equipment and the training of large number of professionals and workers in their use. They also helped to develop incremental R&D in engineering to provide innovative solutions to meet local needs.

Accompanying this, local universities like NTU and NUS were given massive government funds to bring in foreign talent. They provided a number of scholarships to local students to pursue advanced degrees in leading universities in the West to strengthen the teaching and build the research foundation at the two universities. As a result, the science and engineering faculty expanded even further (NUS, Annual Review, 1985).

Nevertheless, during this period, R&D activity in Singapore remained weak. The Science Council that was established in 1967 to encourage industrial product and process development did not actively encourage industrial R&D until the early 1980s. Even then, efforts were limited to the Ministry of Finance formulating an indicative long term R&D plan to serve as a guide to governmental action in this area in 1981 and tax incentives given for manufacturing companies that undertook R&D in Singapore, and an *Initiatives* *in New Technology* scheme that was established in 1984, to help subsidize research projects.

As a result of these efforts, a large local and supporting industry supplying computer components and parts, facilitated by a growing pool of engineering expertise from the polytechnics and universities emerged to service the foreign MNCs. Locals working in MNCs were no longer just learning technologies transferred from parent headquarters, but were beginning to adapt and improve on them through "learning by doing" (Wong, 2003b. p. 44). In response, many MNCs also began to establish international purchasing offices to source their worldwide products and parts and components requirements from Singapore and the region. Singapore's well developed logistics infrastructure provided an efficient, timely and low cost delivery.

R&D Development and Intensification Phase, 1989-2003

By the late 1980s, Singapore had already developed a fairly mature manufacturing sector and a strong presence of high value added manufacturing and service multi-national companies (MNCs). It had already relegated its labour intensive manufacturing activities to Newly Industrializing Economies (NIE) such as Malaysia and Indonesia and had acquired some indigenous technological capability. However with "little dragons", particularly Taiwan and South Korea moving ahead at full speed in various high technology areas, such as semiconductors and computers, Singapore faced a new set of challenges to sustain its high value added manufacturing and service industries and move further up the technology ladder (Hu and Jang-sup, 2002). One way it could do so, was to develop its technological infrastructure; promoting indigenous as well as foreign R&D.

Unlike other newly industrialised economies like those of Korea and Taiwan (Amsden, 1989 and Dahlman and Sananikone, 1990), Singapore's rapid technological development, has until recent years been largely dependent on multinational companies' (MNCs) technology transfers from their headquarters to their subsidiaries in Singapore, rather than on indigenous research and development. About three quarters of Singapore's manufacturing output up to 1999 was contributed by MNCs, and foreign capital constituted more than 60% of the equity capital of manufacturing firms in Singapore in 1999 (Wong, 1999). But now Singapore needed to develop indigenous S&T capabilities to complement MNC-led technological development.

It was against this backdrop of international competition and economic integration that a $2 billion National Technology Plan [24], 1991-1996 was formulated and implemented. The aim of the plan was to ensure that total national expenditure on R&D would reach 2% of GDP by 1995, with a minimum of 50% private sector of this total, and a ratio of number of RSEs engaged in R&D to be at least 40% per 10,000 labour force by 1995. More importantly, distinctive to these R&D plans was that S&T research had to be market pulled and not science pushed. As the Plan stated, " Our Science and Technology research must be results driven… it must produce results eventually relevant to our economic competitiveness" (National Science and Technology Board, 1991). The direction of these changes was perhaps best summed up in the proposed framework in which science and technology would be integrated into Singapore society:

1. That science and technology must be driven by the need to enhance national competitiveness.

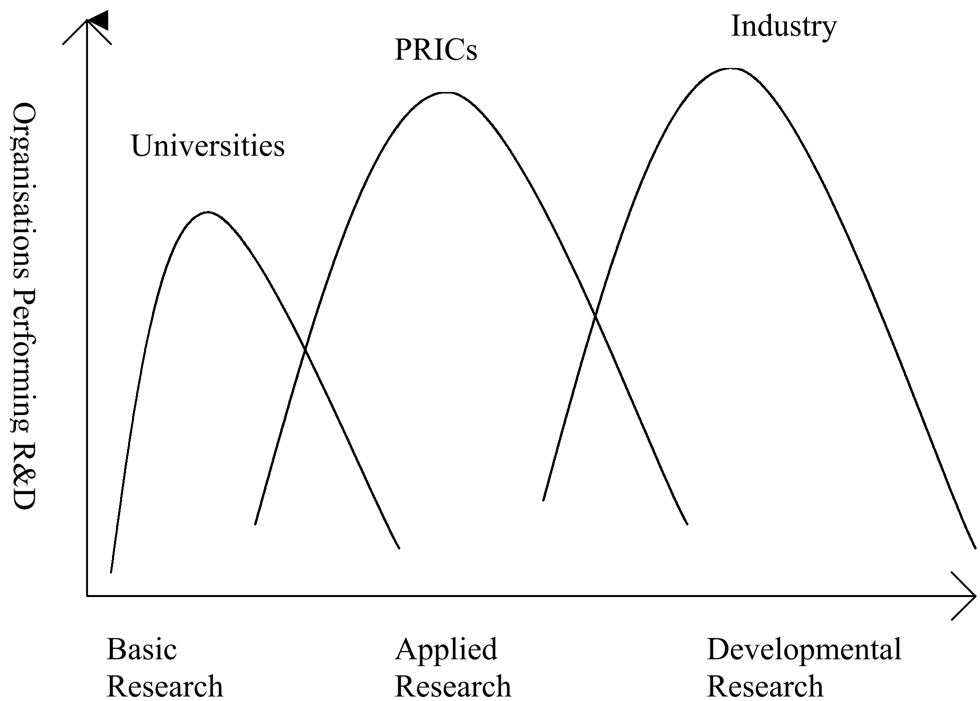
[24] See National Science and technology Board (1991).

2. That excellence in science and technology must be pursued in selected niches relevant to the country's strengths.
3. That the government must work in close collaboration with industry.
4. That the build up of science and technology infrastructure must be result oriented, that is to say that it must produce results eventually relevant to economic competitiveness.
5. That the government's research institutes must support and complement industry efforts by emphasizing generic pre-competitive research and process development.

(National Science and Technology Board, 1991)

For this, the types of R&D and the relevant implementing agencies were first identified. Three different categories for R&D were identified and they were namely basic, applied and developmental R&D. Developmental research refers to the systematic use of the knowledge or understanding gained from research directed towards the production of useful materials, devises, systems or methods. Following this, the plan determined which institutions would be responsible for carrying out the different types of R&D. Generally, the universities would carry out basic R&D, while the PRICs would carry out advanced research and the industry would carry out development research, although they may be some overlaps (See Figure 3). As a result, Baber (2001) observes that "the academic pole of the triple helix is quite under-developed and does not have much bargaining power…" (p. 405).

Figure 3: R&D Allocation in Singapore, 1991



Source: National Science and Technology Board (1991).

Nevertheless, the newly established National Science and Technology Board (NSTB), which supported and allocated R&D funding, set up 13 research institutes and centres to support R&D in industry specific areas, helping to create institutional alliances between the universities and the private industry researchers. These new institutes were mainly located near the universities and the science parks to encourage ties and exchange.

Following this, there was a rapid growth of the public research institutes and centre (PRICs) since the late 1980s both in terms of number and R&D spending. Over 1990-1997, R&D spending by PRICs grew nearly seven fold; faster than the four fold increase experienced by the private R&D sector (See Table 12 and 13). The primary objectives of these PRICs were to develop the applied technological capabilities that are critical to support the major industrial clusters already in existence in Singapore. In addition, some of the institutes were given the task to develop core competencies in new generic technologies such as molecular and cell biology by the Institute of Molecular and Cell Biology (IMCB) that are needed to attract and grow new high tech industries that were non-existent in Singapore at that time.

The eventual objective of this was the creation of an R&D infrastructure, which was planned under the concept of a "technology corridor" that would be located in the south-western part of the island and would include institutions such as NUS, the Science Park, the Business Park, the Singapore Institute of Standards and Industrial Research (SISIR) and NSTB.

In response to this, an increasing number of MNCs were also taking on the technology transfer station roles in Singapore, providing the process engineering know how to develop new processes in support of new products and later transferring them to other countries. Indeed, according to Hang (1999), with the continuing growth of MNCs towards globalization, and with increasing competitive advantage of locating nearer to the major customers and shortening the development cycle, MNCs are setting up R&D centres outside their home base. By 1996, the private sector's share of R&D expenditure had reached 62.7% in 1994 and the number of research scientists and engineers (RSEs) were increasing at an annual rate of 12% between 1991 to 1994 (See Tables 12 and 13).

This plan was followed up by a second $4 billion National Science and technology Plan (NSTP)[25], 1996-2000. The term "Science" was added to underscore the importance of a science base for the long term development of competitive advantage for the nation. Building on the success of the earlier plan, the NSTP set up goals for the next round of S&T development in areas such as R&D expenditure, manpower development in S&T, private sector R&D and technology diffusion and commercialization.

These efforts were relatively successful. By 1999, the number of RSEs had grown more than threefold since 1990, with 13817 RSEs in 1999. R&D expenditure was at 1.84% of GDP in 1999 and R&D expenditures in all sectors had gone up. Patent activity, an indication of research quality, had also gone up, with 673 patents in 1999, a fourfold increase from 1993 (See Tables 12, 14 and 15).

However, when compared to other developed and developing countries, Singapore was still relatively behind. It has caught up with economies like South Korea and Taiwan, but still lags behind economies like the U.S. and Japan. In terms of GERD expenditure percentage of GDP, Singapore had only a 1.8% as compared to the 2.8% of U.S. and 3.1% of Japan (See Table 16.). In an increasingly challenging global environment characterized by intensified competition and rapid technological change, and facing severe domestic labour and resource constraints, Singapore had to tap new sources of economic growth to maintain its competitive edge.

[25] See National Science and technology Board. (1996).

Table 12: Trends for indicators of R&D[26] in Singapore, 1978- 2002

Year	Gross Expenditure on R&D. (GERD) (S$m)	GERD/GDP %	RSEs
1978	37.8	0.21	818
1981	81.00	0.26	1193
1984	214.3	0.54	2401
1987	374.7	0.86	3361
1990	571.7	0.84	4392
1991	756.8	1.00	5218
1992	949.5	1.17	6454
1993	998. 2	1.06	6629
1994	1174.98	1.10	7086
1995	1366.55	1.13	8340
1996	1792.14	1.39	10153
1997	2104.56	1.49	11302
1998	2492.26	1.76	12655
1999	2656.29	1.84	13817
2000	3009.52	1.91	14483
2001	3232.68	2.13	15366
2002	3405.00	2.19	15654

Source: National Survey of R&D in Singapore (various years), NSTB.

[26] R&D here includes basic, applied and developmental research.

Table 13: Number of organizations performing R&D[10],Singapore, 1978-1999.

Year	Private Sector	Higher Education Sector	Government Sector	Public Research Institutes	Total
1978	63	4	23[27]	-	90
1981	135	4	38[11]	-	177
1984	143	4	20[11]	-	167
1987	191	4	20[11]	-	215
1990	266	5	4	7	292
1991	311	5	9	6	331
1992	331	5	13	5	354
1993	410	6	15	5	436
1994	427	6	16	5	454
1995	440	6	14	10	470
1996	496	6	11	13	526
1997	508	6	14	15	543
1998	571	6	13	14	604
1999	593	6	12	13	624

Source: National Survey of R&D in Singapore (Various Years), NSTB.

[27] Figures include public research institute. Definition of government R&D organization was changed from 1990 onwards, resulting in a smaller number of organizations being counted.

Table 14: R&D expenditure by sectors, 1978-2002

Year	Private Sector (S$m)	Higher Education Sector (S$m)	Government Sector (S$m)	PRIC (S$m)	Total (S$m)
1978	25.5	8.2	4.1	-	37.8
1981/82	44.2	24.3	12.5	-	81.0
1984/85	106.7	69.6	38.0	-	214.3
1987/88	225.6	95.4	53.7	-	374.7
1990	309.5	119.7	99.4	43.1	571.7
1991	442.1	147.1	96.8	70.8	756.8
1992	577.6	156.0	105.0	110.8	949.5
1993	618.9	157.3	106.5	115.5	998.2
1994	736.2	179.5	142.1	117.2	1175.0
1995	881.4	193.4	110.4	181.4	1366.6
1996	1133.4	238.7	166.8	253.2	1792.1
1997	1314.5	277.7	216.1	296.2	2104.6
1998	1536.1	305.8	299.8	350.5	2492.3
1999	1670.9	310.0	304.9	370.6	2656.3

Source: National Survey of R&D in Singapore (various years), NSTB.

Table 15: R&D Output indicators for Singapore, various years

	1993	1995	1997	1999	2001
No. of Patents Applied for in the Year	142	242	490	673	1096
No. of Patents awarded for the Year	52	51	132	161	461
Total No. of patents owned as of 31. Dec	200	256	831	1077	1456

Source: National Survey of R&D in Singapore, various years and Intellectual Property Office of Singapore (IPOS) (2004).

Table 16: Comparison between selected countries using basic indicators on S&T development, various years

Countries	Year	GERD/ GPD [%]	RSEs per 10000 workers
France	1997	2.2	61 (1996)
U.S.	1998	2.8	74 (1993)
Japan	1998	3.1	96
Germany	1998	2.3	60
United Kingdom	1998	1.8	55
South Korea	1998	2.5	48
Taiwan	1998	2.0	66
Singapore	1999	1.8	70

Source: Wong (2003b).

This prompted a larger budget of $7 billion dollars being invested in the Science and Technology Plan 2001-2005[28]. Under this plan, more companies were encouraged to embrace high-end R&D, to collaborate with PRICs and universities, especially in the field of life sciences. The area of life sciences, had been touted by former EDB Chairman, Philip Yeo as "the next big thing" because with the completion of the Human Genome Project, which provided an endless amount of possibilities; at the crossroads of biology and computing lay new technologies and frontiers that are now perhaps only at the conceptual stage, and this provides numerous opportunities for income in various areas such as medicine, health care and insurance. For Singapore, according to the government, this focus on life sciences would allow Singapore to complement its pharmaceutical industry as well as enable Singapore to carve a niche for itself in its transition to a KBE (Straits Times, 2000a). Moreover, the life sciences industry was

[28] See Ministry of Trade and Industry. (2000).

increasingly recognised as a high value added one. For example, in 1998, value added per worker in the pharmaceutical industry was about $1.5 million, compared with an average of $100,000 within the entire manufacturing industry (Straits Times, 2000a). Hence, the life sciences were touted to be Singapore's "fourth pillar" of economic growth.

To build Singapore into a life sciences hub, EDB devoted $1 billion alone to get top-class private sector R&D investment into Singapore. Initiatives that followed include the revising of IPRs to better attract R&D companies to Singapore, and as talent was key to the life sciences industry growth, $60 million was allocated to life sciences scholarship over the years of 2000 to 2005; to attract local and overseas researchers to take up R&D in life sciences in Singapore. In addition, *Singapore Education,* an umbrella under the Economic Development Board (EDB) was also launched to develop Singapore as an education hub. World renowned universities such as John Hopkins, MIT have set up their overseas extension campuses in Singapore. The aim of this was to introduce more competition in the university sector, and more importantly, expanding the pool of talent to provide fruitful interaction and collaboration between universities and industry.

Meanwhile and more importantly, the university sector began to undergo major developments. These developments, interestingly, pointed towards the universities playing a more enhanced role in strategic R&D. For one, Deputy Prime Minister, Dr Tony Tan and a team comprising of officials from MOE, NUS and NTU visited 10 universities and 4 organisations in Canada, Hong Kong, the UK and the US to glean best practices from these universities so that Singapore can become the "Boston of the East"[29].

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[29] This model had been adopted to help in Singapore's transition to the knowledge economy because the greater Boston area which boasts of over 200 universities, colleges, research centres and thousands of companies was a focal point of creative energy: a hive of intellectual, research, commercial and social

Subsequently, several recommendations were then made to restructure the university sector. Firstly NUS and NTU were encouraged to adopt a more American system of flexible, market driven, performance based remuneration system. Due to Singapore's colonial heritage, the NUS and NTU structure had been based on a British model; where administration is much more regimented; where faculty recruitment, promotion and determination of salaries are centralized and faculty remuneration is linked to nationally determined pay scales. As such, this system would not attune the university to the needs of the marketplace, and hence the university will not be able to attract and retain the top research scientists. Secondly, to foster excellence in research, the universities has to "work at the cutting edge of knowledge and this generally means that [the university would need to] concentrate on a small number of top quality students and staff and give them the support and opportunities to compete with the best in the world" (Tan, 1997). What this means is that the university should do away with a "one size fits all" approach, but instead focus on training students on specific areas of research. Moreover, NUS and NTU were encouraged to work with a small number of institutes to tackle problems of importance to Singapore, to the extent that their research would be at world-class standards, and encourage the best students to study in these areas. For example, initial plans include the introduction of life sciences into the curriculum at the universities, to encourage more students to carry out R&D in this area.

Finally, universities were to be given further operational autonomy, over and above what they currently enjoy, so that they can respond more quickly to changes in the

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activity. This hive of activity has in turn boosted Boston's economic growth from a manufacturing one to a leading knowledge hub.

environment. In return for this, there would be a greater accountability from the universities to ensure that public funds are properly directed towards the achievement of outcomes and used in an efficient and effective way. As Dr Tan (1999) points out, "to manage and attain excellence, the level of government funding should be linked to the university's goals and deliverables to ensure that the government gets good value from the funds… Government funding should be viewed as having to be earned by our universities and not as automatic entitlements, especially in the realm of research funding". In turn, this environment and the increasing engagement with the industry highlighted earlier facilitated the shift towards technopreneurship in NUS.

Clearly the universities in Singapore were about to play a more important role strategic R&D. These changes proposed would not only encourage R&D at the university, but also encourage the universities to form linkages with the PRICs and the industry. Aptly, Dr Tony Tan (1999) stated that, "a knowledge economy is driven by ideas, innovations, intellectual property and information. Being knowledge intensive institutions, NUS and NTU have the critical role of creating, imparting and applying knowledge in support of national objectives… [this] three facets of the cycle of excellence … are inextricably intertwined. Universities which aspire to play a significant role on a national, regional and global scale must aim to excel in all three areas [creating, imparting and applying knowledge]".

The enhanced role of S&T in Singapore's economy has slowly seen a build up of linkages among universities, industry and PRICs. Initially, R&D was mainly centred around the industry, with the locals just "learning by doing" from the MNCs. But competition from "little dragon" economies prompted a stronger push towards R&D,

with the public sector, via PRICs playing a more active role. These two sectors dominated R&D, with the universities being relegated to playing a more manpower provision and carrying out of basic research roles.

This however changed with Singapore's push towards life sciences. The rapid pace of technological development and the completion of the Human Genome Mapping project meant that new sources of technological innovation were not only possible but also required. The universities, with their resources in R&D and manpower, were in turn thus harnessed to contribute in applied R&D. They were encouraged to engage more with the industry and become institutions of excellence in R&D. As Baber (2001) aptly observes, it is with the emerging emphasis on life sciences that the triple helix model of institutional alliances truly takes place.

4.2. The Application of S&T Knowledge

4.2.1. Technopreneurship

The Technopreneurship phase, 1999-2001

Unlike other newly industrialised economies like those of Korea and Taiwan (Amsden, 1989 and Dahlman and Sananikone, 1990), Singapore's rapid technological development has until recent years, been largely dependent on multinational companies' (MNCs) technology transfers from their headquarters to their subsidiaries in Singapore, rather than on local private companies and Small and Medium Enterprises (SMEs). However, according to Hang (1999), this trend is worrying. He argues that up to 1999, MNCs had been willing to relocate their R&D operations overseas if there were reliable supporting industries in the host country. But this scenario is set to change because in a KBE, the intense global competition and shorter product cycle means that MNCs can no longer afford to wait to transfer technology and to train small and medium enterprises (SMEs). Instead, they would rather go to a country where they can source their components or processing needs from the local SMEs which have the relevant technology. This would enable them to not only deliver their technology more efficiently, but also create more opportunities in the provision of new technological products and services; the provision of technology would help generate feedback to the knowledge creators and jumpstart the next round of innovation. As the former chairman of NSTB, Teo Ming Kian sums up, "Rapid technology advances suggest that, in order for companies to survive, they have no choice but to generate new products and processes to make themselves competitive," (as quoted in Chang, 2000).

The government in turn also recognises the need to encourage the growth of more local businesses. As Vivian Balakrishnan (personal communications, 28 October, 2004), the Senior Minister of State for Ministry of Trade and Industry in charge of entrepreneurship observes, “we [the government] have recognized that the Singapore economy cannot solely rely on the traditional MNC export-led model because other countries can and will leapfrog us …. Simply moving up the value chain will not suffice. Home-grown talents and ideas will have to be harnessed”.

Recognition of this first came about in the Committee on Singapore’s Competitiveness (CSC), Report[30] which had been established to access Singapore’s economic competitiveness over the next 10 years and to recommend strategies and policies to transform Singapore into an advanced and globally competitive knowledge based economy. The committee noted that, "To achieve Singapore's vision as a first-league developed country, we need to develop science, technology and innovation

[30] See Ministry of Trade and Industry (1998).

capabilities to sustain our competitiveness, and reap more value from translating R&D efforts to commercially-viable products and services" (Straits Times, 1998).

The CSC Report recommended specific plans for key sectors including manufacturing and telecommunications to move Singapore up the value chain. Specifically significant and relevant to this discussion here, were these two aims;

- To build world class companies with core competencies to compete in the global economy.
- To nurture and strengthen local enterprise.

Following on these recommendations, key initiatives such as the Industry21 and Technopreneurship21 were implemented.

For example, the Industry21 (I21)[31] was a ten year plan to develop Singapore into a vibrant and robust global hub of knowledge driven industries in manufacturing and traded services with an emphasis on technology, innovation and capabilities. It encourages MNCs to locate more of their key knowledge intensive activities in Singapore and encourage local companies to embrace more knowledge intensive activities and become world class players. I21 also identified electronic, chemicals, engineering, life sciences, education and healthcare, headquarters, communications and media and logistics as key industry clusters to be nurtured.

Meanwhile, a delegation from Singapore, led by Deputy Prime Minister and Defence Minister Tony Tan, went to the U.S. to seek ideas and feedback on how best to proceed with the Republic's plan to become a *technopolis*. The team found out that for centres of excellence in technological entrepreneurship, in places like New York, North Carolina, Boston and Texas, academic institutions, government, community leaders and

[31] See Economic Development Board (1999).

the private sector had worked together to build the conditions for entrepreneurship. It was gleaned that while governments could not put the entrepreneurial spirit into people, it could create the environment where it could grow. In North Carolina, for example, between the late 1950s and 1990s, the economy went from being among the ten poorest to being among the twenty richest states. The single most important factor had been the co-operation of the government, industry and universities (Pereira, 1999).

These findings was translated into the Technopreneurship 21[32] (T21) plan, which involved high level government, universities and private sector efforts to lay the foundation for successful development of technopreneurship sector in Singapore was implemented. The Technopreneur 21 Ministerial Committee (T21MC) was chaired by Deputy Prime Minister Tony Tan, with Second Trade and Industry Minister George Yeo as deputy chairman. Whereas the local start ups in the earlier period were mainly in manufacturing and primarily served as suppliers and contract manufacturers to large MNCs, the new start-ups being promoted during the late 1990s would be more product innovation oriented and increasingly focused on information technology, software, internet applications, biotechnology and life sciences. The NSTB was to lead Singapore in its drive to become a technopolis. As Board chairman Teo Ming Kian emphasizes: "We are interested in the creation of companies and want to create as many as possible" (Santa Maria, 1999).

Initiatives were to be taken in education facilities, financing and education. With regards to regulations, rules and regulations were reviewed to remove obstacles to technopreneurship. Initiatives taken include, among other things, new rulings that allow people to use their homes as offices, there will be tax incentives, and immigration rules

[32] See Economic Development Board (2004).

will be eased to give foreign investors enough time to set up shop here in Singapore. Signalling its support for fledgling businesses, the Government will now be willing to buy from new suppliers, breaking from the long-standing practice of relying on established ones.

With regards to finance, government support came in terms of various assistance schemes. For example, the Technopreneur Investment Incentive (TII) scheme, started in September 1999, provides investors of qualified start-ups with a loss insurance for their investments. The government also provided direct financial help to T21. For example, in April 1999, a US $1 billion Technopreneurship Investment Fund (TIF) was launched by NSTB to attract more venture capital activities to Singapore. The NSTB has also set aside S$100 million to help high-tech foreign and local companies launch their business ventures here. Called Technology Fund II, it will benefit more than 100 companies over the next five years. It will be managed by NSTB subsidiary Technology Development Fund Management, which aims to raise another S$50 million from local and foreign private investors by the end of the year. Education Minister Teo Chee Hean adds that this fund will build on Singapore's earlier initiatives to support local technology start-ups and encourage new foreign companies to sink their roots here. He said that "with Technology Fund II, we hope to carry on the momentum of technopreneurship started by the first fund. We hope to see even more high-tech ventures starting out and more private venture capital seizing the opportunities in investing in emerging technologies in Singapore." (Straits Times, 1997).

Subsequently from 1 January 2000, the policy implementation system for T21 was refined and taken over by EDB, providing greater focus and direction on the technopreneurship drive. They initiated a whole host of schemes, such as the Enterprise Investment Incentive Scheme[33] (EII) (taking over and expanding on the TII), which they jointly manage with the Standards, Productivity and Innovation Board (SPRING), and manage the TIF with a corporatized sector of the EDB known as TIF Ventures[34]. For the life sciences drive that was initiated in 2000, EDB also had three funds, Singapore Bio-innovations, Life Sciences Investments and Pharmbio Growth Fund to assist in various start-ups and projects in this area.

In addition, the venture capital (VC) industry also took off[35]. In Singapore, other than the Venture Capital Group that was created within EDB in 1985 to help develop a vibrant venture capital industry, a Venture Investment Support for Start-ups (VISS) programme[36] was also introduced. The VISS is managed by TIF Pte Ltd and is a $50 million (Singapore Dollars) co-investment program that directly co-invests in early stage promising and strategic companies that are linked or based in Singapore. By 1993, the VC industry had been growing at an impressive rate of over 10% every year, from a fund size of $2.6 billion to over $13 billion in 1993 (Leung, 2003).

In education, initiatives were set in motion to further revamp the prevailing system to foster creative thinking and to use and exploit IT extensively especially at the universities. As Balakrishnan (personal communication, 28 October, 2004) observes, "…the next evolutionary step is to have employees and researchers who independently seek out solutions and seize opportunities they see before them. The civil service too

[33] For further information, see SPRING Singapore (2004).
[34] For further information, see TIF Ventures Pte Ltd (2001)
[35] The venture capital industry provides liquidity to business start-ups in the KBE. By taking equity stakes in the technology enterprises in exchange of cash injection, venture capitalists can also become useful business partners via their experiences in growing businesses and well established networks.
[36] For further information, see TIF Ventures Pte Ltd (2001)

does not want yes-men. Even our army now demands “thinking soldiers.” These revamps in education were particularly significant in the university sector. Revamps in curriculum (the introduction of Technopreneurship Minor Programs for example), admission policies and administration (greater autonomy for universities so that they are not just generators of manpower but also start up companies) were just some of these major changes.

In conclusion, Singapore’s changing S&T policy has created a knowledge infrastructure that consist of growing communication networks between universities, industry and government. Initially only supporting linkages between PRICs and industry, the university has been increasingly encouraged into joining the network. This network is set to become more complex and unstable as the promotion of technopreneurship opens up the opportunities for the creation of more knowledge.

CHAPTER FIVE

TOWARDS NUS GLOBAL ENTERPRISE

Chapter Five: Towards NUS Global Enterprise

5.1. Introduction

One key implication of the triple helix model is the enhanced role of the university. In the previous chapter, we have discussed the increasingly networked knowledge infrastructure of Singapore economy. Now, the role of the universities in Singapore would be explored. Specifically for this thesis, I would be exploring the role of NUS.

For this section, I would firstly examine how NUS has transformed over the years. This is followed by its emerging role as NUS Global Enterprise. Discussion of this would follow in the four key stages that universities in general would undergo to transform into an entrepreneurial university. Finally, the chapter will conclude with an overview of NUS's transformations.

5.2. Transformations in NUS.

NUS was established on 8 August 1980, incorporating the University of Singapore and the Nanyang University. Under the National University Act 1980, NUS is a legal entity; an independent institution that receives funds from the Ministry of Finance. These funds are subject to approval by parliament from time to time and are given as grants in aid to the University. This public status of the university in turn indicates that any approaches to reforms or initiatives made are likely to be top down.

The university's inception clearly reflected this. As Singapore restructured itself to a higher value added, more technology and capital-intensive economy, the supply of highly skilled manpower becomes of key importance. For this, NUS was established with a spectrum of courses, from Engineering, Science, Medicine to Business Administration and spent its first few years developing its undergraduate courses with the government's technical bias towards education in mind. Intake at the university expanded gradually year after year, with the Engineering Faculty having the largest intake and IT was gradually introduced both as a course as well as a platform for training undergraduates.

In addition, the university, with the help of the government, also provided industrial attachments to better upgrade and expand the training of its students. For example, it made an agreement with the Skills Development Fund Secretariat for the Skills Development Fund to be used to support the vacation training of Engineering students by providing grants to employers who offer placements to students during the vacations. This agreement proved to be very positive as a total of 115 firms became involved in the training of the engineering students (NUS Annual Review, 1983).

This focus on teaching however started slowly shifting towards research in 1983. Initial indications of this were seen in the revised salary for faculty members at the university; so as to attract more talented staff, more well equipped facilities for research and the university's focus on developing its postgraduate programs, especially in the Faculties of Engineering and Sciences (NUS Annual Review, 1984).

With the assistance of the government, NUS was also able to attract more postgraduate students. A Research Scholarship Scheme was established to attract more local and overseas students to take up postgraduate studies at the university. The government also set up the Institute of Systems Science at the NUS campus in 1981 to help and engage in the training of postgraduate students. In addition, to jumpstart R&D at the university, NUS engaged in a collaborative research program with the statutory board, *Singapore Telecoms*[37]. This programme known as the NUS-Telecoms Joint Applied R&D Programme would provide the university with an experience for modeling future similar collaborative research programmes with the industry and other statutory authorities.

At the same time, the government also initiated the University's initial link with the industry. The university, although previously informally associated, was formally admitted as a member of the Applied Research Corporation (ARC); a government owned research and consultant company. This formal link in turn meant that the large body of expertise available within the University, its sophisticated laboratory equipment, the facilities of its Libraries and the Computer Centre will all be accessible to outside organizations through ARC consultancy projects. Additionally it also provided enhanced opportunities for close interaction between the University and external bodies in commerce, industry and the public sector.

In 1990, ten years after its establishment, postgraduate student numbers increased especially in the fields of Science and Technology. Similarly, total research projects funded expanded to 1294 (See Table 17).

[37] Singapore Telecoms is now known as Singtel.

Table 17: Growth of post graduate students and research projects at NUS, various years.

Year	Postgraduate Students		Total Research Projects Funded[38]
	Science	Engineering	
1986/87	119	110	-
1987/88	121	135	383
1988/1989	144	177	1204
1989/1990	164	217	1294

Source: National University of Singapore, *Annual Reviews*, Various Years, NUS.

Encouraged by the promising outcome of the joint R&D program with *Singapore Telecoms*, the university started to actively explore similar collaborative efforts with the industry and other statutory boards. Memorandums of Understanding were signed with government agencies like the Public Works Department, National Computer Board, Ministry of National Development and so on. In addition, the Institute of Molecular and Cell Biology (IMCB) was set up in NUS in 1987 to coordinate and direct research activities in biotechnology; an area that was later formally acknowledge in the 1991 Strategic Economic Plan that would be a key area of growth. This in turn also boosted research activities as staff members at various faculties acted as consultants to various public bodies and also served as members on their committees.

With the industry, such collaborations also stepped up. Some of the organizations that the university joined forces with include the Chartered Semiconductors, Maxtor, Pacific Biomedical and so on. In addition, the NUS Technology Associates was set up to get the industry more closely associated with the R&D activities at the university and to encourage the industry to make use of the sophisticated and extensive range of resources

[38] Figure includes ongoing and new research projects

at the university. This was later followed by collaborations in more specific areas which were facilitated by the setting up of Centre for Industrial Collaboration and the Innovation Centre which was set up respectively at the Faculties of Science and Engineering. These centres help to highlight to the industry what academics have to offer in applied research. For example, Centre for Industrial Collaboration launched a publication called *Research Trends,* which will help to promote the faculty's R&D and to help seek contacts with the industry. A Technology Corridor was also established in the Faculty of Engineering to display and highlight projects that demonstrate innovation and originality. These collaborations in turn also lead to industries and professional bodies coming forward to top up research scholarships is that the total emoluments of research scholars will match the starting salaries in the market for top graduates in the corresponding disciplines (NUS Annual Review, 1988).

Meanwhile, at the university, multidisciplinary research was actively promoted. It was hoped that through these multidisciplinary research there will be a "pooling of expertise and resources [that will] … facilitate fruitful interplay of ideas, leading to very productive research" (NUS Annual Review, 1990) and to further encourage greater efforts at creative work, the university revised its rules on patents and copyrights for research findings so as to enable staff to retain a higher proportion of the financial returns arising from the inventions.

These R&D activities intensified as S&T became increasingly important with the establishment of the NTP 1991-1996 and NSTP 1996-2000. As part of the NTP plans, the technology infrastructure of 13 research institutes to support R & D were virtually all located within the NUS campus. Examples included the Institute of Microelectronics

(IME) established in 1991, the National University Medical Institutes (NUMI) established in 1994 and Institute of Molecular Agrobiology (IMA) established in 1995. Also, in 1992, The Magnetics Technology Centre[39], funded by the NSTB and hosted by NUS Faculty of Engineering was launched. The centre, working with postgraduate students at the Engineering Faculty was tasked to undertake industry driven, applied R& D projects in relevant areas of magnetic recording technology.

Also, as part of the M21 plan, where students must be taught to be analytical, creative, entrepreneurial, and possess good problem solving and inter-personal skills, university curriculum was also revamped. Curriculum became more flexible and new programmes such as the Talent Development Programme was launched in July 1996 to produce well-rounded graduates with broad intellectual outlooks. In addition, NUS also entered into partnerships with foreign universities to further encourage the research and intellectual capabilities of their students. Examples of this would include the Singapore-MIT Alliance (SMA) that provided joint postgraduate degrees in the field of Sciences and Engineering.

The Singapore government also recognises that long-term economic development was dependent on a critical mass of educated and skilled work force. Education constitutes a large portion of the country's public expenditure. Up to 1990, tertiary institutions received an increasing proportion of the total education budget; its share rose from 13 percent in 1970, to 16 percent in 1980, and to 26 percent in 1990. Over this time period, the share allocated to primary education declined. Higher education expenditure increases were kept in line with increases in student numbers because high quality education costs more money, and student subsidies were essential to improve equality of

[39] The Magnetics Technology Centre was renamed the Data Storage Institute in 2001.

opportunity as well as to attract talent into higher education, particularly into economically critical fields of study.

Nevertheless, the recession of the mid-1980s had resulted in government subsidies to higher education to be reduced and a policy of greater cost-recovery through tuition fees has been instituted. The eventual objective was to lower the student subsidy to around 70 percent of tuition costs, to reduce the over-dependence of public tertiary institutions on government funding, and to introduce an activity-based funding mechanism. That is, the aim was to subsidize tertiary institutions for up to 60 percent of their operating costs, with capital expenditures still being funded mainly by the government. The institutions on the other hand, would generate the remaining balance (40 percent) from tuition fees, user charges and other non-governmental sources.

In response, tertiary institutions have adopted policies to diversify their revenue sources. For example, from 1992, tuition fees would increase between five to seven percent annually to keep pace with wage and other cost increases. In addition, institutions have established endowment funds to tap non- government sources. The two universities, with government support, have launched a $1 billion Universities Endowment Fund. The income generated from this fund is to be used exclusively to support special and innovative projects, as well as develop programs which will nurture intellectual development and research.

More recently, however, NUS is turning towards the industry for sources of funding. The ongoing projects that NUS have been increasingly involved in (See Table 15), do not only include the government, but also the industry. For example, collaboration with the industry and government was intensified by the Bioprocessing

Technology Unit (BTU) which was set up in the Faculty of Engineering with major funding from the EDB and Kaneka Singapore. The BTU, which is the first project to be funded under a $20 million Biotechnology Competence Enhancement Programme administered by the EDB, was to serve the twin objectives of providing industry based research and building indigenous research capabilities. Initiatives such as the launch of NUS's campus wide optical fibre network, NUSNET, which was launched in April, 1991, plugging NUS into a world network of about 3000 academic and industrial institutions through the Internet, and the 1994 NUS and NSTB jointly established Adjunct Research Appointment scheme in NUS, aiming to enable NUS to appoint senior industry researchers and managers to undertake part time R&D work in NUS, particularly in the Faculties of Engineering and Science, further demonstrated the university's increasing engagement with the industry.

This need to engage with the industry was perhaps best encapsulated in the forming of the Industry and Technology Relations Office (INTRO) in 1992. The Office was to provide a one stop information and service centre for the industry and further promote collaborative R&D between NUS and industry, and also facilitate technology transfer to industry through licensing, consultancy, manpower training and commercialization of research findings (NUS Annual Review, 1992).

In summary, NUS has clearly undergone what Etzkowitz (1999) describes as the *first academic revolution*. From teaching, it has slowly shifted to R&D. More specifically, its R&D is increasingly being engaged with not just the PRICs, but also the industry. All this provides NUS with not only the capability and resources to carry out

R&D, but also the necessary linkages to enable more private and lucrative channels for knowledge dissemination and commodification.

5.3. Towards NUS Global Enterprise

5.3.1. Internal Transformation of NUS.

The emergence of academic entrepreneurs in NUS actually took place even before the emergence of the KBE. In the 1980s, when academics going into business was almost unheard of, Prof Jacob Phang, an engineering lecturer at NUS, convinced the then Vice Chancellor, Prof. Lim Pin that he wanted to be both a lecturer and a businessman. An invention hatched by him and colleagues in the laboratories had met with a favourable response from the industry, with people wanting to pay money for it. That was when the team started to seriously think about commercializing their invention, not just by licensing its patent but by creating a spin off company. As Prof. Phang (personal communication, 22 July, 2004) commented, "in 1988 when we came out with this idea of starting a company, we were in some ways the pioneers because ideas like this were not expressed before. Although this wasn't new in other universities like MIT and Stanford [who have] done [sic] this quite extensively".

But the road to commercialization was not without glitches. Although permission had been granted by the vice-chancellor, the university lacked the infrastructure and support to help set up the company. Indeed, over the next one and a half years, Prof. Phang and his team tried to sell their business plans to more than ten venture capitalists and other investors. But each time, they were shown the door and told that their project was too risky; the industry had wanted some positive sales figures before they would invest. Eventually, the team themselves came up with the starting capital and today, the company known as *Image Transforms* has a turnover of $20 million in 1998. NUS have also benefited, earning royalties of at least $100, 000 by 1996 (Seah, 1996).

Prof. Phang's success in turn has encouraged more researchers to move their products from the laboratories to the market place. According to Prof. Hang, NUS Deputy Vice-Chancellor, two events played key roles in jumpstarting this trend. One was the success of Prof. Phang's company and another was the setting up of the Industry and Technology Relations Office (INTRO) in 1992, which promoted the partnership between the university and the industry. This role of INTRO however slowly expanded over the years as more researchers started to commercialise their research. It became responsible for the commercialization of University created intellectual property and the formation of technology spin off companies and this was apparent when INTRO published NUS's first *NUS Technology Directory* in 1993 and a book titled, a "Guide to Patenting, Technology Transfer and Research Collaboration with Industry" in 1994. The office also administered the INTROLINK programme that provides the industry with the platform for interaction and access to expertise and physical resources of NUS.

By 1995, the INTRO had set up NUS Technology Holdings Pte Ltd (NUSH), a private company wholly owned by the university to facilitate the commercialization of university research units and inventions through the formation of spin off companies and technology ventures. With the formation of NUSH, technology spin off companies from NUS totalled up to seven[40] by 1995.

[40] These seven companies included Biotreat International Pte Ltd, Allegro Science Pte Ltd, Everbloom Mushroom Pte Ltd, Image Transforms Pte Ltd, Eutech Cybernetics Pte Ltd, Kentridge Instruments Pte Ltd and MedInfo Systems Pte Ltd.

More importantly, this trend reflected the changing mindset academics had about their research findings and the growing interest of the government and industry in forging a closer relationship with the university. As a Straits Times (1996a) article observed, more researchers at NUS are commercializing their research projects and seeing more enquiries from the industry. NUS had launched four research projects recently with funding from NSTB, where researchers would spend the next five years creating and inventing cutting edge technology even before the industry needs it. That is, at NUS, the value-added watchword is alive in four projects - micro-electronics and materials science among them - which its scientists just started on even before industry has indicated a need (ST, 1996b). For this, the ST observed that,

> One aspect is that the National University of Singapore, even the much younger Nanyang Technological University, should no longer be regarded as conveyor belts churning out graduates to fill jobs… But, in step with higher post-graduate enrolments, both universities have developed a research capability aimed not only at meeting specific needs of industry, but also to anticipate the requirements of an economy that keeps transforming itself. (ST, 1996b).

This entrepreneurship role was further strengthened in 2000, with Singapore's focus on life sciences. An Office of Life Sciences was set up in 2001 to integrate life sciences research and teaching through out the university. This was done to encourage and hopefully encourage more students to carry out R&D in life sciences. This was further supported by research scholarships provided by EDB as mentioned earlier in Chapter Four. However, NUS did not just stop at these initiatives.

With the dearth in research funding earlier, NUS begin to take advantage of the endless possibilities that this new area of research could bring. For this, it set up a whole variety of research institutes and centres at the university and faculty level, dedicated at meeting the strategic needs of the industry and government (See Figure 4.). These research institutes and centre in turn provided more sources of funding for NUS.

Furthermore, encouraged by the recommendations made by the government earlier about autonomy, its administration and the need for talented R&D staff, pay structures at NUS were also revised. Pay structures for faculty members were revised; instead of the usual civil service salary structures, pay would be accorded accordingly by performance and market factors and only performance will decide promotions and increments. This means that only "star" professors will be awarded with performance bonuses, fellowships and one-off monetary awards (Straits Times, 2000b). As NUS Vice Chancellor, Shih Choon Fong noted, "If we [NUS] want to recruit someone very outstanding, someone who can contribute in an area very strategic to Singapore, I would have to offer him a higher salary than my own" (as cited in Davie, 2000).

In addition, NUS also set up a new interdisciplinary graduate school, the Graduate School of Integrative Sciences and Engineering, headed by executive director, Prof. Barry Halliwell, to capture the opportunities that R&D in S&T would bring. The NUS graduate school (NGS) is a university-wide endeavour aimed at spearheading world-class trans-disciplinary graduate education and research in science, engineering and medicine. The students enrolled in NGS are supervised by leading staff from NUS, the Research Institutes and Industry. To attract talented and motivated graduate students to undertake doctoral studies, NGS has assembled top faculty with a keen interest in mentoring students. In addition, students get the chance to engage in globally competitive cutting-edge research, made possible though NGS' collaboration with A*STAR research institutes. Professor Shih said that collaboration with A*STAR research institutes would establish a critical mass of researchers, academics and students to undertake bold trans-disciplinary research in exciting and strategic areas. As he noted, “we envision NGS to be among the world’s leading graduate schools within 10 years, nurturing top-notch researchers for Singapore” (as cited in NGS, 2002).

The industry in turn has responded favourably. Dr Gurinder Shahi, chief executive of BioEnterprise Asia, which incubates life-sciences start-ups here, said Singapore could start by encouraging academics to spend time in the commercial sphere. “Academics are too comfortable. There's just too much risk going commercial” (sic), he said. Professor Edison Liu, director of the Genome Institute of Singapore, also said that one reason for South Korea's success was that scientists were allowed to 'move in and out of academia to take that risk'. He said: 'One of the roles of academia is to be a safe haven for creative people. We must be able to give them a home, so if they take five years out of their lives to take that risk, they have a chance of coming back” (as cited in Straits Times, 2001).

These changes were clearly distinct from the past. According to Professor Barry Halliwell (personal communication, 31 July, 2004), “when the government decided that Singapore should make more of an impact in life sciences, it didn’t look at the university at all. It founded IMCB…” But today, at NUS, there are life sciences programs that overlap extensively with research institutes and centres and also programs that are unique to NUS (Halliwell, 31 July, 2004).

By 2001, the number of graduate research students at NUS had almost doubled, reaching 5005 in 2001 (See Table 18.). More importantly, R&D efforts at NUS had intensified. According to the 2003 *Global Entrepreneurship Monitor Report*, people with university education and above displayed the highest level of entrepreneurial activities, with its total entrepreneurial activities (TEA) rating going up from 4.1% to 9.6% in 2003 (See Table 19.) (Wong et. al, 2004). In NUS, Patent filed grew increasingly between the years of 1997 to 2000, with 21 patents being granted in 2001 (See Table 20).

Table 18: No. of research students at NUS, Various years

Year	No of Research Students
1997	2088
1998	3052
1999	3510
2000	3457
2001	5005

Source: NUS *Annual Review*, 2002.

Table 19: Level of Entrepreneurship Activity in Singapore by Education, 2002 to 2003.

	2003 TEA (%)	2002 TEA (%)
No Formal Education	1.9	7.3
Primary	1.2	7.7
Secondary	4.1	5.3
Polytechnics	6.4	4.2
University and above	9.6	4.1

Source: Foo, Wong and Wong, *Global Entrepreneurship Monitor Report,* 2004

Table 20: Trend in Patents Filed and Granted in NUS, 1997 to 2000

Year	Patent Filed	Patent Granted
1997	52	9
1998	75	18
1999	103	12
2000	130	21

Source: NUS *Annual Review*, various years.

Furthermore, the NUS Alumni, in 2003 was revamped and segregated into two offices. One office, the Development Office provides leadership in fund raising for the university. Its purpose is to inspire and honour philanthropy and the practice of giving to NUS, so as to substantially build the NUS endowment and the resources of the University. As of 2001, funding from these sources and from the industry accounted for 11% of total overall funding. Meanwhile, the NUS Alumni office, focused on "friend raising" (Office of Alumni Relations, personal communication, 18 July, 2004), trying to create a bond between graduates and its alma mater. This "alumni centricity"[41] approach was geared at creating networks, which would better link past NUS graduates in the industry and government, with NUS. The NUS Alumni Office works closely with the other units of the university like the NUS Entrepreneurship Centre and the NUS Extension, which provides educational courses for graduates interested to further upgrade their skills, allowing the university to tap on the expertise of their alumni as well as to engage them with lifelong learning and learning by doing opportunities that are key to a knowledge based economy. All this not only ensures the supply of key manpower but also places the university in a good position to take advantage of its established base in research.

In Vice-Chancellor Shih Choon Fong's inauguration speech, he announced his vision of NUS being to Singapore what Stanford was to Silicon Valley, that of an "intellectual and entrepreneurial pulse of Singapore [and] the confluence of local and foreign talent" (2000). For this, he spearheaded major organizational changes. In 2001, NUS unveiled its new corporate identity that carried a stylized branding to symbolize a forward-looking organisation. A new vision and a new mission were articulated for the

[41] These networks are considered important because they could for example, bring in successful alumni such as Olivia Lum, President of a local listed company, Hyflux, to assist in start ups at the university.

University. The NUS vision was now, "*Towards a global knowledge enterprise, building synergies between education, research and entrepreneurship*" and the NUS mission was to "*Advance knowledge and foster innovation, educate students and nurture talent, in service of country and society*", positioning NUS to embrace new challenges and seize new opportunities in a rapidly innovating knowledge-driven global economy. NUS is now also re-organized along three lines, the academic, the corporate and enterprise cluster, like a corporation. This clear division of duties was to enable the university to take advantage of its new entrepreneurial role (See Figure 5).

NUS Research Infrastructure

NUS Affiliated National Research Institutes/ Centres	With A*STAR: Bioinfomatics Institute (BI), Bioprocessing Technology Institute (BTI), Data Storage Institute (DSI), Genome Institute of Singapore (GIS), Institute for Chemical and Engineering Sciences (ICES), Institute for Inforcomm Research (I2R), Institute of Bioengineering and Nanotecnology (IBN), Institute of High Performance Computing (IHPC), Institute of Materials Research and Engineering (IMRE), Institute of Microelectronics (IME), Institute of Molecular and Cell , Biology and Temasek Life Sciences Laboratary
University Level Research Institutes/ Centres	Asia Research Institute (ARI), Centre for Remote Imaging, Sensing and Processing (CRISP), Institute of Engineering Science (IES), Nanoscience and Nanotechnology Initiative, Singapore Synchroton Light Source (SSLS), Temasek Laboratories, The Logistics Institute and Tropical Marine Science Institute
Faculty Based Research Institutes/ Centres.	Examples include: At School of Business: Centre for Business research and development, Centre for e-business, NUS-SPRING Centre for best practices At School of Computing: Algorithms Lab, Centre for information Mining and Extraction (CHIME), Centre for Internet research (CIR), Centre for Systems Security, Colloboration Technology Research Centre, Computational Linguistics Lab, Computer Graphics Lab, Computer Systems Lab, Database Lab, Information System Research Lab, Laboratory for E-commerce, Learning Environment and Learning Science Lab, Medical Computing Lab, Multimedia Computing Lab, Programing Languages and Systems Lab, Resource Allocation and Scheduling Lab and Software Engineering Lab. At Faculty of Engineering: Centre for advanced chemical Engineering (CACHE)

Figure 4: Research Infrastructure at NUS

NUS Administration

Office of the President

Academic Cluster

- Office of the Provost
- Office of Life Sciences
- Centre for Development of Teaching & Learning
- Centre for Instructional Technology (CIT)
- Office of Admissions
- Registrar's Office
- Office of Research
- Faculties and Schools
- NUS-affililated National Research Centres/Institutes
- University-level Research Centres/Institutes
- Faculty-based Research Centres/Institutes
- NUS Libraries
- Office of Student Affairs

Corporate Cluster

- Office of Alumni Relations
- Computer Centre
- Office of Corporate Relations
- Development Office
- Office of Estate & Development
- Office of Finance
- Office of Human Resources
- Internal Audit Unit
- International Relations Office
- NUS Museums
- Office of Quality Management
- Office of Safety, Health & Environment
- The Centre for the Arts
- University Health and Wellness Centre

Enterprise Cluster

- NUS Enterprise
- NUS Entrepreneurship Centre
- NUS Overseas Colleges
- NUS Consulting
- NUS INTRO
- NUS Extension
- NUS Publishing
- NUS Venture Support

Figure 5: NUS Administration

5.3.2. Trans-institutional impact between the three helices.

The Singapore government played a key role in facilitating the creation of trans-institutional arrangements between the three helices. This was, for one, most apparent in the creation of science parks; which was aimed at enabling the key actors of the triple helix to engage in close communication. Furthermore, as S&T became increasingly important, NSTB rebranded itself in 2002, as the Agency of Science, Technology and Research (A*STAR)[42], to take on a more active role in promoting, funding and managing information about the possibilities of R&D in Singapore, with an aim to foster, "world class scientific research and talent for a vibrant knowledge based Singapore" (A*STAR, 2003). The agency is divided into four key units, namely the Biomedical Research Council (BMRC), the Science and Engineering Research Council (SERC), Exploit Technologies Pte Ltd (ETPL) and A* Graduate Academy (A*GA).

The BMRC, established in October 2000, supports, oversees and co-ordinates public sector biomedical research and development activities in Singapore. It is headed by an Executive Committee made up of members from the government, industry and universities. The Executive Committee also draws on the combined experience of renowned scientists in the Biomedical Sciences International Advisory Council. BMCR funds five key research institutes, namely, IMCB, Institute of Bioengineering and Nanotechnology (IBN), Genome Institute of Singapore (GIS), Bioprocessing Technological Institute (BTI) and BioInfomatics Institute (BII), all of which are mainly located at NUS or affiliated with the university. These research capabilities in turn support biomedical science companies such as Novartis, Eli Lilly, Chugai, ViaCell, Siemens Medical, that have set up R&D operations in Singapore. BMRC also sponsors

[42] See A*STAR (2003)

international partnerships aiming to raise the level of biomedical research in Singapore by increasing the researchers' knowledge and skills through exposure to world-class research work and interaction with fellow scientists in international research institutions. These partnerships include the Karolinska Institute (KI) & NUS partnership and the Singapore-MIT alliance. SERC meanwhile promotes public sector research and development in Science and Engineering with a focus on fields essential to Singapore's manufacturing industry. Similar to the BMCR, it has a council made up of diverse members, funds key research institutes and engages actively with the other key actors in the helix through joint partnerships.

Both BMCR and SERC would "overlook and coordinate research across institutions, centres and universities", says Prof. Hang, who headed the BMCR in 2000 (as cited in ST, 2000a). This in turn means that centres wishing to conduct research in the same area would have to compete under a new bidding system, giving councils a good overview and be able to coordinate efforts and resources to achieve the best results. The councils will also be responsible for developing manpower to supply high-end research efforts and will be looking to develop a pool of post-doctoral fellows in the universities (Soh, 2000). This effort is mainly administered via A*GA. For example, a major initiative under the A*GA has been the A*Graduate Scholarship that was launched in 2003. The aim of this new graduate scholarship scheme initiated is to boost the number of PhD holders who will be able to do multi-disciplinary work covering the biomedical sciences, the physical sciences and engineering. Eventually, they will become a key attraction for MNCs to move their high-end research projects to Singapore, as A*Star chairman Philip Yeo notes, 'When we spoke to companies, the first thing they ask is how many PhDs we have. To start up one research and development facility here, a company needs 30 to 50 PhDs,' (Au-Yong, 2003). This A* Graduate Scholarship has been used to support graduate student at the NGS at NUS.

ETPL is the commercialisation arm of A*STAR in Singapore that not only promotes an excellence in science, engineering and biomedical research, but also nurtures talent to help advance Singapore's transition to a knowledge-based economy. ETPL is positioned to identify, protect and exploit Intellectual Property (IP) created by the Research Institutes (RIs). It works with the A*STAR researchers to generate and exploit IP for the benefit of Singapore and also the industry on licensing IP generated by our RIs. Through targeted programs such as GET-Up (Growing Enterprises with Technology Upgrade) program, A*STAR harnesses the expertise built up over the past decade in the Science & Engineering RIs to help local companies upgrade themselves technologically.

In addition, a "Biopolis" hub was to be established. It is strategically located in the Buona Vista area (One-North), near the National University of Singapore, the National University Hospital and the Singapore Science Parks, encouraging multidisciplinary collaborations and partnerships between academia and industry. This research complex is the epicentre of Singapore's biomedical research activities and will house the full spectrum of Biomedical Sciences R&D activities, encompassing basic drug discovery research, clinical development and medical devices research. The aim of Biopolis is to seed the growth of a vibrant research community by bringing together biomed-related research institutes and private companies. Designed to attract overseas investment and encourage the formation of local biotech start-ups, the Biopolis would provide space for lab-based R&D activities tailored to Biomedical Sciences companies. Companies located at the Biopolis would also be able to leverage on the Hub's shared facilities. The Hub also features modern conference and business support facilities, restaurants, banking and retail operations, as well as administration, legal and financial services. The five main research institutes, BI, BTI, GIS, IBN and IMCB will be co-located at the Biopolis.

As Deputy Prime Minister Tony Tan, who also heads the Life Sciences Ministerial Committee notes, “Such a close interface between researchers from industry and scientists from research institutes will accelerate the translation of new discoveries to marketable products… [and hence] Biopolis represents a vision to establish the entire value chain of biomedical-sciences activities in Singapore - from research and development to manufacturing and health-care delivery…” (Soh, 2000). Similarly, Paul Herrling, head of corporate research and chairman of Novartis Institute for Tropical Diseases (NITD) adds that, “We wanted to be close to where the patients are and where the treating doctors are, so that we could design our therapy. You also need to be able to attract top scientific talent; you can’t do that in the middle of the jungle. You need a high level scientific environment that gives your scientists close proximity to other scientists.” (Gwynne, 2003). The Science Park together with the Biopolis would eventually be absorbed into “one north”, the new 200 hector stretch of research and development in Singapore.

The industry in turn has responded favourably. Even before Biopolis has been fully completed, it had a 90% occupancy level with key industry players like Novartis, Eli Lilly, Chugai, ViaCell, Siemens Medical setting up their R&D operations to capitalize on Biopolis's excellent research infrastructure.

In the area of entrepreneurship, the Trade Development Board (TDB) and the Productivity and Standards Board (PSB) have been repositioned and renamed International Enterprise Singapore (IE Singapore)[43] and Standards, Productivity and Innovation Board (SPRING) Singapore respectively in April 2002, to reflect their new foci in the new economy. IE Singapore will spearhead the building of Singapore's external economic wing by helping promising Singapore-based companies to internationalise. SPRING Singapore will undertake the new role of promoting innovation as a key contributor of productivity growth in a knowledge-driven economy. These units work closely with the universities and industry. For example, the Start-up Enterprise Development Scheme (SEEDS), a $50 million fund which was launched on 1st Oct 2001 with the aim of providing equity financing for start-ups in the seed stage of enterprise formation, also works to help NUS fund spin-off firms. According to Wong (personal communication, 13 July, 2004), for every dollar that the university provides for the funding of a new start up, the SEED scheme would match it dollar for dollar.

In addition, EDB also launched a *Global Entrepolis@Singapore*[44] event for enterprise, innovation and technology. This event positioned Singapore as a platform for the exchange of ideas and technology, discovery of technology and securing of partners, fundings and business deals; enabling more networking to take place between industry, universities and government.

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[43] See International Enterprise Singapore (2004) at http://www.iesingapore.com/.
[44] See Global Entrepolis@ Singapore (2004) at http://www.globalentrepolis.com/en/home/

5.3. Interface processes within NUS.

In his State of the University Address, Vice Chancellor Shih Choon Fong (2001) spoke of NUS today being in a global ecosystem, one which provides new challenges for the university because there is now "intense competition for talent, ideas and capital… [which] flow quickly, unimpeded by boundaries. Furthermore, education and research have become a fast-moving growth industry. There are no barriers or boundaries against entry into this industry" For this NUS had to strive for global academic and entrepreneurial excellence.

For this, the university needed to adopt a "One university, two systems" model. One system would support academic programs and this academic-scholarship oriented system remains the mainstay of NUS. The other, the NUS Enterprise, would support creative entrepreneurship. NUS Enterprise would exist as a free enterprise zone, where potential university entrepreneurs are released, and to some extent protected, from conventional rules of setting up a new company, allowing for greater flexibility and faster response. NUS Enterprise is also a platform from which major university innovations can be launched and the boundaries of entrepreneurial practices tested and pushed.

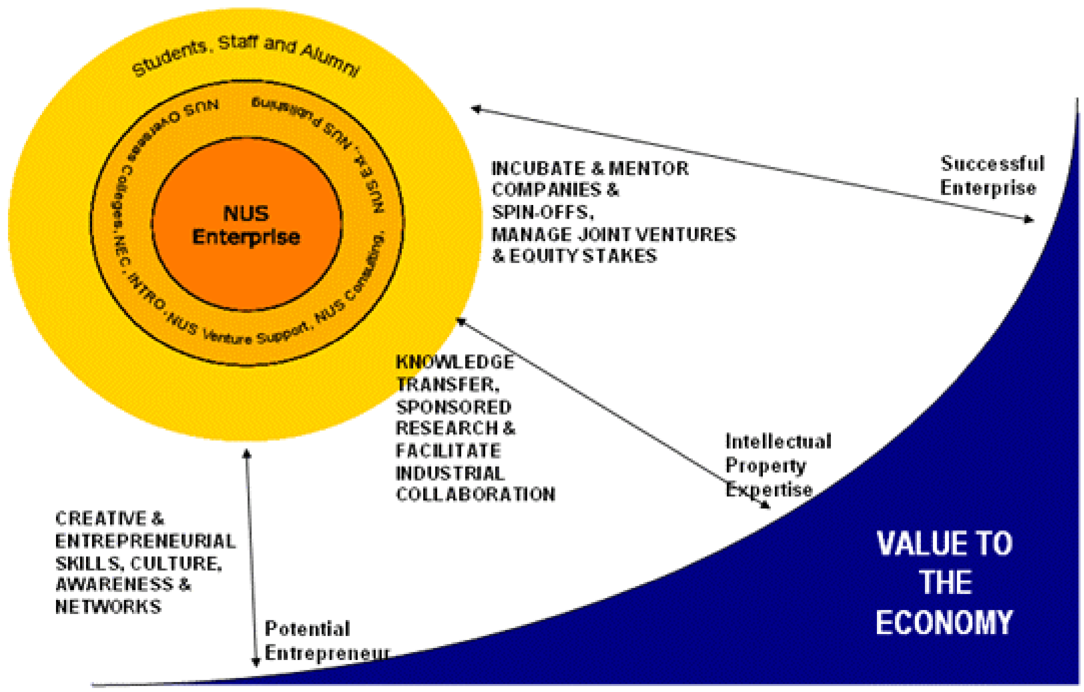
NUS Enterprise was formed in October 2001. Its vision is to inject an enterprise dimension to NUS teaching and research involving NUS students, staff and alumni. Its aim includes;

1. To provide entrepreneurship education and nurture talents with a global mindset;
2. To identify, protect and commercialise intellectual property;
3. To nurture NUS spin- offs and start-ups;
4. To foster industrial collaboration between the University and external bodies; and

5. To facilitate the dissemination of NUS knowledge to the external community.

(NUS Enterprise Handbook, 2001) (See Figure 6.)

Figure 6: Knowledge Enterprise Ecosystem



Source: NUS Enterprise Handbook 2001

NUS Enterprise comprises of seven units (see Figure 7), of which the following four are directly related to entrepreneurship in the University: NUS Entrepreneurship Centre (NEC), NUS Industry and Technology Relations Office (INTRO), NUS Overseas Colleges and NUS Venture Support. Each of these units performs a specific function in facilitating the setting up of new companies and promoting a general culture of entrepreneurship in the NUS community.

In addition to these four units, there are three other units at NUS Enterprise: NUS Extension, NUS Consulting and NUS Publishing. These three units do not relate directly to entrepreneurship within the University, but they will be given a brief description here. NUS Consulting furnishes confidential and independent consultancy services to industry and government and encourages NUS staff to get involved in multi-disciplinary projects and to extend their knowledge beyond academic confines. NUS Extension offers opportunities in lifelong learning and continuing education in professional development for NUS alumni as well as for the community at large. NUS Publishing publishes scholarly and academic books in both traditional print form as well as in online and digital form. It is also the channel where NUS knowledge is disseminated to the external communities both locally and around the world (See Figure 7.).

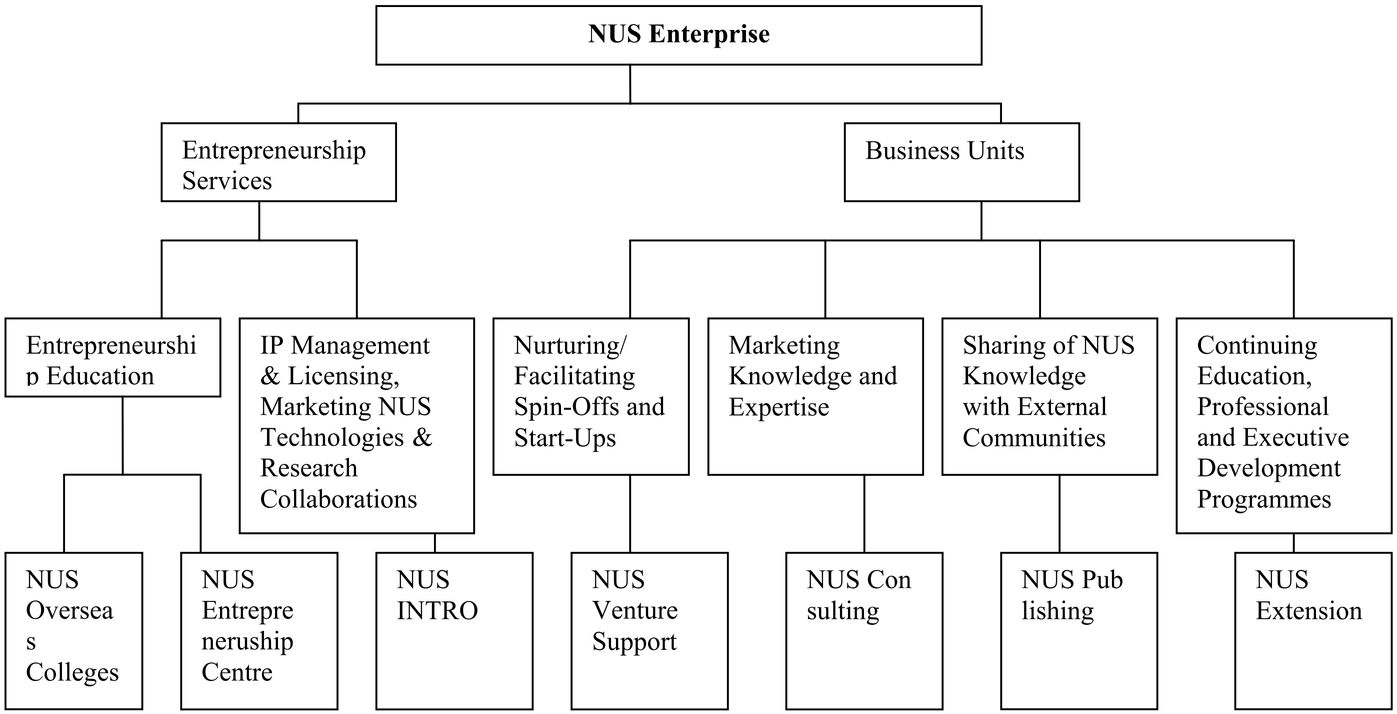


Figure 7: NUS Enterprise Organizational Structure, 2001.

Source: NUS Enterprise Handbook (2001).

NUS Entrepreneurship Centre (NEC)

NEC aims to build a dynamic NUS community with a pervasive entrepreneurial and innovative culture and a global reputation for leadership in entrepreneurship education via its core activities of education, outreach and research.

With education, NEC has an academic teaching unit offering a wide range of Technopreneurship-related academic courses that are open to all NUS students. These include:

- A Technopreneurship Minor Program for Undergraduate Students in NUS campus and NUS Overseas Colleges. The Minor Program comprises six modules covering key aspects of entrepreneurship, including Entrepreneurial Marketing, New Product Development and New Venture Creation.
- Technopreneurship Elective Courses for Graduate Students, especially those from Engineering, Science and Computing
- Technopreneurship Workshops for engineering students in the Technopreneurship Incubation Program (TIP) and SMA students.

NEC also conducts a wide range of Continuing Education Programs on Entrepreneurship and Innovation for NUS Alumni and the larger Venture Community in Singapore. These include:

- Technopreneurship Workshop for Scientists, Engineers and Technical Managers (in collaboration with outside organizations such as the Institution of Engineers Singapore (IES) and Singapore Technologies Group)
- Executive Education Programs for High Tech Managers, Entrepreneurs and Policy Makers

With its Outreach function, the aim is to raise awareness and interest in entrepreneurship among the NUS community, so NEC has pioneered a wide range of Outreach activities, including:

- Start-Up@Singapore, an annual business plan competition open to all Singapore residents (since 1999) & Mentored CEOs Growth Program for Start-Up@Singapore participants
- A series of international business plan competitions, including StartUp@Asia , Global Entrepreneurs Challenge, in collaboration with Stanford and GlobalStartUp@Singapore, in collaboration with INSEAD

These activities not only bring the entrepreneurial buzz to Singapore and global venture community to the NUS campus, but also enable NUS to build a strong social network of contacts with entrepreneurs, venture capitalists, angel investors, high tech CEOs, and other venture professionals in Singapore and world-wide.

NEC also conducts research on key issues of technology entrepreneurship in collaboration with leading entrepreneurship researchers and research institutions overseas. The centre aims to understand the underlying forces and factors that drive the dynamics of birth and growth of technology enterprises, and to identify the best venturing practices for success in the global marketplace. The centre also works closely with leading public policy researchers worldwide to benchmark Singapore's enterprise ecosystem vs. leading high tech hotspots in the world and to identify best policy practices for promoting knowledge-based entrepreneurial growth. Examples of recent NEC research projects include:

- First National Innovation Survey of Singapore (funded by EDB)

- Resource acquisition strategies by technology entrepreneurs in Singapore and China
- Innovation strategies and performance of Singaporean firms
- Global Entrepreneurship Monitor (GEM) Study – The benchmarking of Singapore's entrepreneurial propensity vs. countries worldwide (with partial funding by EDB)

By integrating education, research and outreach activities, NEC hopes to create an entrepreneurial environment in the University and to advance the knowledge of technology venturing practices for University entrepreneurs. These activities are aimed at bringing the entrepreneurial world into the NUS campus and propel NUS's innovation and enterprise into the business community. In line with the Global Knowledge Enterprise vision of NUS, NEC also collaborates with leading entrepreneurial universities and institutions in the world to develop and implement quality education outreach and research programmes in innovation and entrepreneurship.

NUS Overseas College

NUS Enterprise's joint efforts with other universities have resulted in overseas entrepreneurship study and internship programmes for NUS students. NUS Overseas Colleges is one such programme. It provides NUS undergraduate students with the opportunities to gain all-round experience combining work with study, by immersing themselves fully in the vibrant entrepreneurial environments around the world. Integrating entrepreneurship education with mainstream undergraduate degree programmes is also aimed at cultivating within students an entrepreneurial outlook in their academic work and to equip them with the business skills necessary for converting their academic knowledge into commercial products.

NUS Overseas Colleges students are selected from the various faculties of the University to spend one year as full-time interns in technology-based firms while attending entrepreneurship courses on a part-time basis at a partner university. Currently, NUS has a college in Philadelphia, known as NUS College in Bio Valley (NUSBV), NUS College in Shanghai and a NUS College in Silicon Valley.

NUS INTRO

Since its formation in 1992, INTRO has been a key unit of the University and the NUS Enterprise Cluster. Its role in turn has also been expanding as the university increasingly takes on an entrepreneurial dimension. Today, it is the one-stop centre for all NUS patent protection and commercialization services.

INTRO has three basic functions. Firstly, it licenses and manages intellectual property at NUS; by licensing and managing NUS intellectual property, INTRO helps to convert discoveries and innovations of NUS researchers into products and services that are useful to the general public, thereby commercializing University intellectual property. Secondly, it builds relationships between NUS and industry partners by facilitating sponsored research and other collaborative agreements with private corporations, research institutes and other agencies, and thirdly, it helps market NUS technologies both locally and worldwide. INTRO has also recently launched an online Technology and Expertise Directory to help University start-ups source for expertise and gain access to the University's research capabilities.

For this, INTRO was restructured into two main sections, the Office of Technology Transfer (OTT) and the Office of Research Contracts (ORC) to better reflect the nature of its work. The Office of Technology Transfers deals with intellectual property management and licensing, and technology marketing.

The OTT protects and manages NUS intellectual property, and helps to translate new discoveries and innovations by NUS researchers into useful products and services for the benefit of society by licensing these technologies to existing companies or start-ups. That is, OTT evaluates invention disclosures from NUS staff and students to determine the feasibility of commercialising the technology and whether protection of the Intellectual Property is necessary for effective commercialisation. Applications by NUS staff and students to patent inventions are also managed by OTT, which handles the entire process, leading to the granting of patents by the US or any other territory. Hence OTT represent the University to negotiate with interested parties on the licensing of NUS technologies. These technologies may be licensed by NUS start-ups, established companies or institutions.

OTT also carries out Technology Marketing, an initiative launched in January 2003 to create awareness of NUS technologies, and cultivate NUS-industry relationships with the objective of transferring the results of NUS research, innovation and expertise to society for its ultimate benefit. OTT adopts a proactive approach in project marketing. It actively sources industry partners interested in licensing NUS technologies or to collaborate on joint research projects. Strategic partnerships with other organisations to achieve these aims are also pursued. OTT encourages and stimulates interaction and networking between NUS researchers and industry. Together with its strategic partners, it organises events, roundtable discussions and seminars on a regular basis, creating opportunities for NUS staff and industry to meet.

The ORC meanwhile establishes policies and guidelines, help draft, and negotiate various research agreements with external parties to facilitate collaborative research. ORC negotiates on the University's behalf with external parties to facilitate various research agreements between NUS and these external parties, which can be other educational institutions, research centres, commercial companies or government agencies. ORC deals with Research Collaboration Agreements, Memoranda of Understanding, Non Disclosure Agreements or Confidentiality Agreements, and Letters of Understanding.

In doing this, the University's Intellectual Property Rights need to be protected and its reputation as a premier academic institution maintained. ORC also manages and protects the University's Intellectual Property Rights, including patents, trade marks, service marks, registered designs, copyright, design rights, know-how, confidential information, trade and business names.

5.4.Recursive Effects

In addition, NUS has also stepped up its efforts in creating start-ups and spin offs by providing venture support and business incubator facilities. As Balakrishnan (personal communication, 28 October, 2004) observed,

> The university has always been a source of new knowledge and transmission of new ideas. What may have been lacking in the past were the resources and capabilities to commercialize that knowledge – to translate knowledge into a relevant product or service in the market. The unfortunate result of that was that our laboratories and research institutes may be coming up with a groundbreaking discovery or technology, but fail to reap the returns. This is the gap that the

universities have been trying to fill in collaboration with the private sector and the Government.

For this, NUS set up the units of NUS Venture Support and NUS Business Incubator.

NUS Venture Support (NVS)

NVS was set up to nurture and facilitate technology start-ups founded by NUS staff, students and alumni. NVS provides the necessary framework and environment to encourage the success of new businesses established on NUS technology and expertise. The objective is to accelerate business growth and help NUS start-ups develop to a stage where they are able to receive significant external funding and graduate to the commercial market place.

This one-stop entrepreneurship ecosystem helps NUS start-ups from the initial seed stage, to starting-up the company, and eventually in venturing into foreign markets. It offers support services and business networks that add value to NUS start-ups, by leveraging on NUS's intellectual property, domain expertise and incubator facilities, to give companies a launching pad into global markets. Its core business activities are:

- New Venture Creation (NVS)
- Business Incubation (NBI)
- Overseas Business Centre

NVS taps on a pool of specialists and professionals who will assist start-ups in evaluating their business plan and link them to a wide network of business mentors, advisors and investors. As Mr Wong Sang Wuoh, the Manager at NVS explains, "We are a facilitator. We also value add... [we] do all the secretarial and incorporation work. We even have an incubation facility here if he wishes to start his company and park it here and get value add from our staff where we have links linking up to his customers and investors and help him develop his business plan… (Wong, personal communication, 13 July, 2004).

In addition, eligible start-ups can receive financial assistance through The NUS Venture Support Fund (NVSF) which is set up to provide seed funding for NUS spin-off and start-up companies, and assist them so that they become attractive candidates for significant external funding. By helping the spin-off and start-up companies, NUS promotes the spirit of entrepreneurship. The amount of funding is subject to the scope and nature of the business proposal, each successful business proposal may be granted a seed funding up to S$300,000.00. The amount will be determined by the Venture Support Steering Committee (VSSC) on a case by case basis, based on funding requirements to reach specific milestones outlined in the business proposal.

At the NUS Business Incubator (NBI), which is managed by NUS Venture Support, the unit provides physical facilities and infrastructure such as, office space and equipment, as well as access to a wide network of professional resources, which includes mentors, advisors and consultants, to assist companies in business development and networking opportunities. Situated at the NUS Kent Ridge Campus, these incubators are located at the School of Computing, Faculty of Medicine and the Faculty of Engineering. This segregation of incubation facilities at these specific areas assist in the start up of spin off companies. As Mr Hui Kwok Leong, the head of NBI states, " …the School of Computing, Faculty of Medicine and Engineering incubators actually play a crucial role in the start up of spin off companies as they cater to a very early stage of the company;

i.e. the R&D and product development stage". (Leong, personal communications, 25 July, 2004). Infect, NBI is currently looking at expanding these incubator facilities by setting up an *incubator network*, linking NUS incubators, local incubators and overseas incubator centres together.

In addition, the start-ups will be also able to tap on the expertise and research network of the University via a *Business Know How Network*, which supports spin off companies in terms of business development and networking with venture capitalists.

Meanwhile, OBCs will be set up in key entrepreneurial hubs around the world to provide a smooth entry for local NUS start-ups into foreign markets. The first Overseas Business Centre, named the NUS Enterprise Centre in Silicon Valley (NECSV), began operations in April 2003.

According to the NUS Enterprise Handbook (2001), the setting up of NUS Enterprise was considered fairly successful. In 2000, before NUS Enterprise was formed, the University signed 80 collaborative research agreements with external corporate parties. The scope and potential for more of these joint research projects was evident, and the funding received as a result proving to be invaluable support for initiating and furthering more important research. Rather than allow these joint projects to exist as disparate, random ventures scattered in the different University faculties, an entrepreneurial arm of the University helped to promote and manage such collaborations, as well as to cultivate a general culture of entrepreneurship in the University. After NUS Enterprise was formed in October 2001, a further 240 agreements were sealed in 2001 and 2002. Backing up these collaborative research projects was a total of S$76 million in funding for sponsored research from both private companies and government organizations.

In addition, as the University become increasingly involved with industry through research and development, spin-off companies and consulting job, the number of areas in which a conflict of interest might arise between University staff and students, and external organizations increase. To manage this heightened sensitivity, the University has drawn up policies and guidelines to help safeguard against *conflict of interest*; this arises when a member of staff furthers her or his own personal gain at the expense of his duties to the University and these duties include, primarily, teaching and research, but also any other University activities that the member of staff may be asked to undertake, and to help mediate when a conflict of interest has arisen.

To address these concerns, the University has drawn up a set of preventative guideline which lists the concrete measures that help guard against a conflict of interest. In addition, some faculties have devised their own set of guidelines which address concerns specific to their field of research. For instance, the Faculty of Medicine has come up with its own guidelines which cater for the medical profession, which has perhaps more occasion for conflicts of interest to arise than any other field because of the proliferation of commercialized inventions by medical researchers.

In conclusion, NUS has experienced Etzkowitz's (1998) two stages of academic revolution. In the second stage, NUS has, according to the triple helix model, adopted the features that characterise an entrepreneurial university. It has entrepreneurial scientists, an industrial penumbra within and around itself and has also enhanced its technology transfer infrastructure.

CHAPTER SIX

CONCLUSION AND DISCUSSION

Chapter Six: Conclusion and Discussion

6.1. The evolution towards an entrepreneurial university: The NUS Experience

With knowledge and information becoming a critical component of economic advantage and intellectual capital a pivotal source, the university as a traditional repository of knowledge is expected to undergo transformations. One way to examine why and what changes have occurred is to examine the evolutionary and dynamic relations between the university, industry and government in the context of the changing economic environment.

Before the emergence of the KBE, NUS had its roots as a teaching university when it was first founded in 1980. Being a state funded university, many of the initiatives that it took were often top down and served public policy purposes. The initial role of trained manpower provider for example, served Singapore's first industrialization phase well. Similarly, its turn towards R&D later was also justified in Singapore's shift up the manufacturing value chain. This however, began to change with the emergence of the KBE.

As S&T played a broader role in the economic development of a KBE, relations between the key actors; university, industry and government became increasingly intense. One key reason for this was the shortening time frame between investigation and utilization, as well as the increasing recognition for the twin theoretical and practical impetuses to S&T research, which had made it obvious that advancement and capitalization of knowledge was intertwined. In Singapore, the need to facilitate further linkages between all three actors took on an added urgency with the completion of the

Human Genome Project, which had immense implications and opportunities for Singapore's growing life sciences industry.

For this, the government revamped its key administrative unit for S&T, renaming it A*STAR. A*STAR would be governed by a council that consist of members from the government, industry and university, allowing them co-ordinate and direct R&D funding. For another, the government also created the science park, *Biopolis*, which is situated near NUS and the PRICs, providing the industry with an opportunity to network and work with them. The industry has responded favourably, with *Biopolis* enjoying a 90% occupancy rate even before it has been fully developed and funding for R&D activities at NUS by industry increasing, with a total by $76 million in funding from the government and industry in 2002. Infect, the industry's growing intention to engage NUS, beyond just R&D partnerships, is perhaps best indicated when its staff are now increasingly members of the university. The pharmaceutical company, *Novartis* has its research staff working at NUS to supervise the R&D work carried out by the graduate students. Efforts were also made to commercialise results in this area. Technopreoneurship was promoted and supported by EDB via various funding schemes such as SEEDS scheme. Events like *Global Entrepolis@Singapore* provided a platform for university and industry to network and co-start a spin-off company.

To encourage NUS to interact further with the industry, the government proposed greater autonomy and reduced funding for the university, with the latter being made more sever with the expansion of the university sector, where the introduction of a third university, the Singapore Management University made the competition for funds even tighter. Furthermore the introduction of top foreign universities in Singapore as part of

EDB's plan to make Singapore an education hub made the competition for talent even harder.

In response, NUS began to look at the S&T knowledge it produced from a dual perspective; that should not only lead to advancement, but also commercialization. Simply put, S&T knowledge was to be redefined as intellectual property with commercial value. Entrepreneurial activities at NUS was however not new, although previously, there had been very little supporting infrastructure for scientists to commercialise their R&D results. But with the directives taken by the government and industry, NUS "reinvented" itself. It set up a unit within the university known as *NUS Enterprise*, which consist of various subunits like *NUS Entrepreneurship Centre*, the *Office of Technology Transfer*, the *Office of Research Contracts*, *NUS Extension* and etc, all which would help promote entrepreneurship at NUS and network NUS with the industry. It even set up the *NUS Venture Support* and *Business Incubator* that would encourage the formation of spin-off companies. This provision of infrastructure has in turn created an entrepreneurial culture among the faculty members. In 2003, the university was listed as one of the top patent filers in Singapore (See Table 18.).

In addition, an industrial penumbra has been generated within the university. As academic-industry relations intensify, academic can be expected to take on industrial characteristics. NUS became organised like a corporate entity, with three key clusters; namely the academic, enterprise and corporate cluster, and research institutes and centres and new interdisciplinary units such as NGS was set up to take advantage of the opportunities that R&D provides. Even the Alumni has been re-organised to better network with the industry.

The use of a triple helix model to examine the evolutionary and dynamic relations between NUS, industry and government has therefore helped to provide an insight into what role NUS would play in the KBE. The institutional spheres of industry, government and NUS, which formerly had separate institutional identities, missions and purposes, are now overlapping with linkages among them. They also take on the roles of the others. The government is acting as a public entrepreneur, encouraging these developments via its various funding schemes. The industry is increasingly taking on the role of academia, by offering its staff to take on positions in the NUS to nurture R&D.

More importantly, NUS is increasingly taking on the role of industry by assisting in the creation of start-up companies. This, together with the technology transfer infrastructure to commercialize research, entrepreneurial culture and industrial penumbra within NUS has resulted in it undergoing a "second academic revolution", taking on an entrepreneurial role and changing its purpose to one that makes it an engine of economic growth.

Nevertheless, these transformations towards an entrepreneurial role are not expected to be stable. In 2003, an inter-ministry committee that had been established to recommend a long term structure for the university sector, submitted its report to the Ministry of Education with the recommendations of giving further autonomy to NUS and making NUS a multi-campus university (Ministry of Education, 2003). These recommendations, if accepted and implemented, would most likely bring about a new round of changes in all three spheres.

6.2. Discussion: The Future of the University

This thesis sets out to address three research objectives. In **Chapter Four**, I have established that the emergence of a KBE where S&T are key priorities have resulted in closer relations between the three key actors of the triple helix model in Singapore. Government policies have been made to facilitate further interaction between university, industry and PRICs. In **Chapter Five**, I have addressed how NUS has responded to these initiatives. By mapping NUS's response, I have demonstrated that the role of NUS in the KBE has been that of an entrepreneurial one. The remaining objective of this thesis is to examine what the implications of this new role are for the future of NUS and to offer suggestions to facilitate any changes. This shall be discussed as follows.

Need for Knowledge Management

As knowledge creation and dissemination become more important economic activities, issues of search and filter would influence the utility of knowledge. It is crucial that the people not only have the specific knowledge but also that they must be able to tell which are the relevant knowledge is. However, searching and filtering codified knowledge or information does require the construction of specific capabilities and substantial investment.

Increasingly today, complex organisations face mounting problems in knowledge management. Knowledge management refers to the process of assessing the knowledge needs of an organisation via the competence embodied in personnel, the need for efficient organisation of this competence and making sure that their needs are met (Earl, 1997). For example, the costs of information production may be an incentive to producers of to find ways to economize on production; by finding ways to re-use and adapt information that has been previously produced. This clearly then requires a more complex "search and filter" process because it is not just about who has the information or where it is stored, but rather who is able to solve the particular problem and know which information is relevant. As Steinmueller (2002) aptly observes, this is perhaps related to the "networked" qualities of knowledge

According to *Fortune* editor, Thomas Stewart (as cited in Fuller, 2002), fast food chains like McDonalds are "smart organisations" because it maximises the interconnectivity of its staff's activities to make the most of its relatively ill-trained staff. On the other hand, universities, although being knowledge repositories, are "dumb organisations" because they are "high on human capital" but "low on structural capital". This trend is further accelerated as the university embarks on the new role of entrepreneurship and engages with the market, clearly reflecting that the university is ill-prepared to manage its knowledge.

Fuller (2003) observes that the dumbness in university is "most clearly manifested in the enforcement of mutually exclusive, even competing, standards for the evaluation of teaching and research, thereby ensuring that the university will appear to be suboptimally performing" (p. 231). Furthermore, for example, when dealing with the market, the university has been very narrow minded, seeking to recognise change only in places where there are obvious and large financial returns to be derived. In the meantime, entrepreneurial and networking activities in other areas, especially non S&T areas are generally ignored.

At NUS, this has clearly been the case. The interconnectivity of S&T related faculties like Medicine, Science and Engineering are all strongly facilitated in terms of the creation of new units like the Graduate School of Integrative Sciences and Engineering. On the other hand, faculties like the Arts and Social Sciences are usually and relatively left out. In meeting the demands of the marketplace, it has also been S&T areas that have received the most support. As Prof. Phang states that, "we want graduates who will start high technology, global businesses. It is businesses such as these that will bring the next wave of growth for Singapore" (as cited in Davie, 2004). NUS it seems, is not maximising the fully networked qualities of its knowledge; not tapping into the potential of non-S&T areas of knowledge.

This situation is further exuberated when one considers problems of regulations. According to David and Foray (2002), the past two decades have witnessed growing efforts to assert and enforce IPRS over S&T knowledge. This sudden trend to privatise property has given rise to a rather paradoxical situation (Foray, 1999). The technological conditions (such as codification and low cost transmission) may be right for individuals to be able to enjoy instant and unfretted access to new knowledge, but a proliferation of IPR prevents access to such knowledge. In other words, the opportunities for more creative creation of new knowledge are limited due to the lack of access to knowledge. On the other hand however, creators of knowledge also require incentives to continue producing knowledge and so their IPR needs to be enforced. Herein then lays the paradoxical situation.

In Singapore, NUS has seen a rise in patenting activities. There is an INTRO unit that helps to commercialize and protect the intellectual property of knowledge creators.

However, this trend however must be balanced against the need to let other user's access, so that the potentiality of creating new knowledge can be maximised. Jacob and Hellstrom (2000) suggest that what is needed for the university to survive in the long run is a strategy in which network context and knowledge assets guide intervention and facilitation. That is, universities should facilitate the networking and sharing of knowledge whenever necessary. In NUS, the setting up of the online Technology and Expertise Directory to help University start-ups source for expertise and gain access to the University's research capabilities is useful, but it still has to ensure that costs in using these information are limited and monitored.

More importantly, with the emergence of these two trends, the university must not be "blinded" from its role as a public institution. Unlike firms that will go bust due to the lack of continuous profits, the university has a public role to play and hence should not deviate away to the extent that it can no longer maintain its original identity.

Source for attracting Talents.

According to Richard Florida (1999), the success of academic led innovations in technology based regions like Silicon Valley and the Route 128 region surrounding Boston and Cambridge have led universities to be "naively" viewed as engines of economic growth. Although these models can be replicated, the key to the success of these models is that the communities surrounding the universities must have the capability to absorb and exploit the S&T knowledge that the university generates. Simply put, the "university is a necessary but not sufficient condition" (p.74) for economic growth. Instead, a more important and frequently neglected role of the university is to be the base for attracting talents. Highly skilled people are mobile and they tend to not only respond to monetary incentives alone, but they would also want to be around smart people. The university can thus play a magnetic role in the attraction of talent.

In Singapore, NUS has often been used as a base for attracting talents. Talented and highly sought after scientists like Prof. Edison Liu and Prof. Barry Halliwell have been cited as contributing to the vibrant life sciences community and close linkages between university, industry and government (Gwynne, 2003) for their decision to come to Singapore. Due to their presence, more students have been attracted to take up R&D in the life sciences (See Gwynne, 2003).

This role of the university was recently reaffirmed by Deputy Prime Minister, Dr Tony Tan (2004), after his evaluation on the state of R&D in Singapore. He affirms that, "An active private sector R&D environment, with a dynamic flow of talented individuals across academia, PRICs and industry will create more opportunities for high calibre scientists and researchers to work in Singapore".

University Alumni as Source of Funding.

If the university had to attract talent, it would need funding. With funding from government increasingly shrinking, the logical step has been to turn towards the industry. According to Fuller (2003), there are two different models in which the university can adopt when turning towards the industry for funding. For one, it can be like a "fast food franchise based on satisfying specific but transient consumer demand" or it could be more of an "independent church, based on servicing [the] more vague, but deeper dispositions on people's lives" (p. 232). He strongly encourages the latter, which means a shift in the burden of funding from tuition fees to lifelong alumni support which would be then used to finance scholarships and recruit the next generation of alumni. That is, the university could emerge as a key institution in offering people a sequence of opportunities of retraining at each era of life. This is a powerful case opening up for universities to concentrate upon the entire life course and act as a resource for facilitating personal and social development.

In NUS, the importance of alumni has only recently been recognised despite an alumni office being present since 1989. At the graduation ceremonies in 2004, President Shih noted that some of the alumni of the university felt “neglected by their alma mater” and this was going to change because the university was now committed to recognising alumni members as key members of the community, where a “warm and supportive” campus environment would be created for them to network (as cited in Lee, 2004). For this, initiatives have been taken, including the building of a $45 million Alumni Complex on campus which will open in 2007 and the revamping of the NUS Alumni website.

A Fourth Helix.

This expanded role of the university to provide social and personal development can perhaps complement the addition of a fourth helix to the triple helix model. According to Parayil (2003), the triple helix should include a public, “civil society” element to take account of consumers and social movements by Non-Government Organisations (NGOs), because they are a key stakeholder in providing resistance and regulatory pressure. For this, the triple helix ought to include this element by making it a foundation of innovation (see Figure 8.).

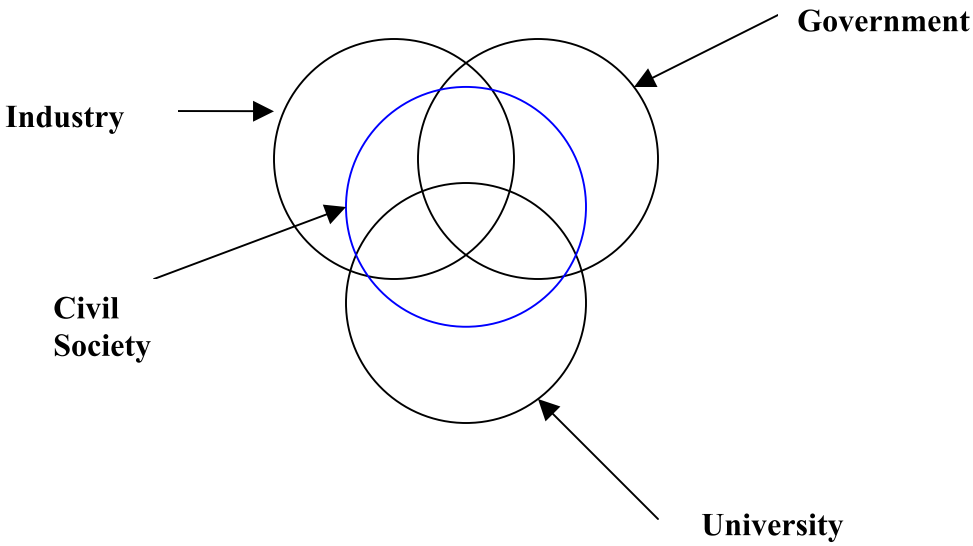


Figure 8: The Fourth Helix of the Public

Indeed, rapid innovations in the field of S&T today means that the public are more often than not left out of the loop in changes. In Singapore for example, the push towards life sciences and its subsequent changes at the universities often follow a top down approach, with public feedback playing minor roles. This trend however has recently taken a reverse direction. Recently, the government has affirmed the important role of the public in all national issues by updating its Instruction Manual; which contains the rules and guidelines for the civil services, requiring that all ministries and statutory boards be required to hold public consultations before formulating and implementing any policies (Chia, 2004).

In this, NUS can play an important role, as to not only educating the public, but also taking advantage of its networks with the government and industry to open up new avenues of communication between all the relevant parties.

In conclusion, NUS's shift towards an entrepreneurial role is not without its complications. Foremost in this is the issue of knowledge management. NUS must ensure that despite engaging more with the marketplace, it still has an infrastructure that would maximise information sharing, protect IPRs and yet gives incentives for further knowledge creation. With regards to roles and administration, NUS should plug into Alumni networks for funding and consider playing roles as being a key source for attracting talent as well as an avenue for public involvement between government and industry.

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APPENDIX:

INTERVIEW QUESTIONS

Appendix: Interview Questions

Interview Questions with Prof. Barry Halliwell, Executive Director of NGS on NGS.

1. NUS Graduate School of integrative science and engineering (NGS) was established recently, last year in fact.

    a. Could you tell me what was the impetus behind the setting up of this graduate school? Was this initiated by NUS or ASTAR? I understand from speaking with some EDB personnel that whenever the government is interested in pursuing a new area of research, they would usually approach the industry first and than NUS to discuss the setting up of a new programme. NUS would than deliberate over the recommendation and if it is acceptable, the programme will be established.
    b. How is this graduate school funded? Mainly by ASTAR?
    c. I observe that on the list of supervisors available, that there is only one industry research scientist involved. Are there any future plans to engage increasingly with the industry?
    d. President Shih once commented that it is very difficult to promote science, because there is so much uncertainty. Like how do you tell a person say ten years ago about the power or benefits of Information technology. Was it difficult to encourage local or foreign students to take up this programme? How has the response been so far?

2. Other than NUS Graduate School of Integrative Science and Engineering, there have been a also in recent years the setting up of other trans or multi disciplinary graduate and undergraduate programmes, for example, the graduate school of Bioengineering, the setting up of the Office of Life Sciences that offer multidisciplinary modules from various departments.
    a. Why and what do you think of this surge in multidisciplinary programmes?

3. I understand that you are also one of the key academics involved in NUS Extension's partnership with University of California, San Diego to impart knowledge to the local industry and to promote a life long learning in life sciences.

    a. Can you comment on this initiative?
    b. How has the response been so far?
    c. At NGS, the post grad students are also encouraged to mentor or engage with students at the colleges and schools in the area of life sciences. Could you elaborate further on this?

4. You once commented that you have observed that there is a close dialogue developing between NUS ASTAR EDB and RI as to how to best work together and leverage each other's resources to make Singapore a major player in life science

research, attract key industry in this area, and also in terms of supporting them with the necessary manpower.

a. Do you think that, this kind of dialogue, which some scholars call a triple helix model of university, industry and government crucial? And would you also say that this is especially important for the creation of innovation in life sciences?
b. And how do you think that this relationship between the three have changed over the years since the government's initial push into life sciences as part of the Industry21 plan?
c. You are an academic who deals actively with both the industry and the government. How do you think these two actors perceive the university today? How do

5. Recently, there have been a number of reports in the newspaper that highlighted NUS's achievements in R&D, its increased activities in the filing, licensing and commercializing of patents as well as its generation of spin off and start up companies in the field of Science and Technology. The Head of NUS Enterprise, Prof. Jacob Phang, has also talked about how these activities will lead the next wave of economic growth for Singapore.

    a. How do you think NUS is competing with government and industry based research institutes?
    b. Do you think NUS can play a key role in leading the next wave of Singapore's economic growth?

6. NUS clearly seems to be taking a great deal of initiatives at promoting life sciences and multidisciplinary research, and is dedicating a substantial amount of resources in terms of manpower and finance. There clearly is a great deal of uncertainty and risk in these areas of research.

    a. How do you feel about this?

7. In President Shih Choon Fong's state of university address in 2002, he talked about NUS moving towards an entrepreneurial role. Being an academic,

    a. How do you feel about NUS's shift towards entrepreneurship?

    b. How do you feel about this new role with regards to its more traditional one of research and teaching? (Do you think they complement each other? Should one play a more important role?Or should the university not engage too much with the industry?

8. In the shift towards this role, there have been a lot of talk about NUS achieving Global Excellance in research, education and enterprise, that NUS needs to compare itself to global standards and lead globally. They have also been changes like

professors' salary being tied to their performance and the setting up NUS Enterprise to engage the university in innovation and entrepreneurship.

a. For this, do you think that NUS is increasingly taking on a more corporate administration?
b. Do you think that the university is ready to be evaluated like a corporate organization?

Interview Questions with OAR, Anonymous

1. The Office of Alumni Relations (OAR) has undergone three major changes, in terms of names, duties and etc, since its inception in 1989. Can you comment on the impetus behind these changes?

2. President Shih Choon Fong recently mentioned in the Straits Times that some alumni have mentioned that they do not identify strongly with NUS and felt "neglected by their alma mater". How has OAR responded to this issue?

3. On the OAR website, it is listed that OAR's approaches to its strategic plans include *cultivating students*, *focusing on branding*, *using information* and *increasing communication between various disciplines*. Can you elaborate further on these various approaches?

4. As seen on the OAR website, some of the core functions of OAR include fundraising and core services.

    a. Could you elaborate further on the function of fundraising? Specifically, how different is that function from that carried out by the Office of Development?
    b. Could you also further elaborate on the core services function?

5. OAR has embarked recently on a road to alumni-centricity, to better engage with NUS's vision of a Global Knowledge Enterprise. Can you comment on how OAR has contributed to this vision so far?

6. Does OAR engage with the other units such as the NUS Enterprise or Office of Corporate Relations to fulfill the vision of NUS being a Global Knowledge Enterprise? If so, could you elaborate on how this is so.

7. How would you, in your own words, today describe the role of OAR in NUS?

8. Are you aware that NUS is increasingly moving towards an entrepreneurship role? What are your views on this shift?

Interview questions with Dr Vivian Balakrishnan, Senior Minister of State for Trade and Industry (MTI) in charge of entrepreneurship on entrepreneurship and the role of the university in Singapore

1. Given the synergistic relationship within your portfolio as the Senior Minister of State for Trade and Industry (MTI) in charge of entrepreneurship and the Acting Minister of Community Development, Youth and Sports (MCYS), do you feel that tertiary institutions in Singapore can be a nurturing ground for youths to become budding entrepreneurs?

2. From the government's perspectives, can you comment on the universities' role in promoting entrepreneurship in Singapore?

3. Was the university a key component in entrepreneurship plans when the drive for entrepreneurship first begun?

4. From the government's perspective, how has the role of universities in helping to promote entrepreneurship evolved?

5. In response to the entrepreneurship drive, universities like National University of Singapore (NUS) have set up the NUS Enterprise unit to give an entrepreneurial dimension to the university. What do you think of this?

6. Recently, the head of NUS Enterprise, Prof Jacob Phang commented in the Straits Times that high tech spin-offs or businesses would bring about the next wave of growth for Singapore. NUS has in recent years been playing an active and fairly successful role in promoting high tech technopreneurship. Do you think that the university can become an important engine for growth in the future?

7. Can you comment on Singapore's efforts at fostering entrepreneurship so far?

8. What are some of your future plans or initiatives in the promotion of entrepreneurship in Singapore?

Interview Questions with Mr Hui Kwok Leong, Head, Business Incubation, NUS Venture Support

1. NUS Venture Support, Business Incubator (BI) is currently located at the NUS Kent Ridge campus, with three incubators, namely the School of Computing, Faculty of Medicine Incubation Centres and the Faculty of Engineering Technopreneurship Incubation Programme. How have this location and the segregation of incubation facilities in these respective areas help in the start up of spin off companies from NUS?

2. Other than housing spin off companies, the BI unit also has a *Business Know How Network,* which supports spin off companies in terms of business development and networking with venture capitalist.
   a) How do BI's existing partners and mentors in this network fulfil this function?
   b) What other partners is BI looking for to further assist these spin off companies?

3. BI is also in the process of setting up an *incubator network*, linking the NUS incubator, local incubators and overseas incubator centers together.
   a) Which local incubator centers is BI considering linking up with?
   b) Which overseas incubator centers is BI considering linking up with?
   c) How does BI makes its selection regarding the incubation centers to link up with?

4. Based on your experience,
   a) What are some of the problems that BI faces when linking up with venture capitalists, partners and other incubators?
   b) What are some of the problems that BI face when they try to network between incubating companies and industry players such as the venture capitalists?

5. Are you aware that NUS is increasingly shifting from a public research/teaching to a corporatized organization?

6. How do you think a commercial shift will affect the traditional roles of teaching and research in a university, especially with regards to NUS?

7. What are your views on this transition?

Interview Questions with Prof. Jacob Phang, Head of NUS Enterprise on NUS Enterprise.

1. Being one of the pioneer lecturer cum entrepreneur or technopreneur and the pioneer in co-founding NUS's first spin off company, Semicaps Corporation. Can you comment on how different the environment in the university was than for entrepreneurship as compared to now?
    a. How has NUS Enterprise, in its various units contributed to this?

2. I also understand that you are the head of NUS INTRO. Now, one of the key activities of NUS INTRO is research contract negotiation and management. You represent the university in negotiating and drafting research collaborations and agreements with industry, government and research institutes.
    a. Could you elaborate a little bit further on this role of NUS INTRO? As in, do faculty members approach NUS INTRO to carry out these activities or do you usually work with departments in helping them link up with the industry?

3. Some scholars have suggested a "triple-helix" relationship between industry-university and government. How would you characterise the communication channels and relationship between the university-government-industry today?
    a. As the director of NUS Enterprise, how has the setting up of NUS Enterprise changed these relationships?

4. There have been many reports in the newspapers in recent years talking about transformations in NUS (For example, the setting up of NUS Colleges overseas and even the setting up of NUS Enterprise) and more recently, the reports have focused on how NUS Enterprise activities have facilitated the generation of more high tech global start ups such as FriarTuck and that the university is increasingly filing and commercializing patents.
    a. With regards to this, how do you think the government's perception of the university has changed? Do you think that the university will play a key role in the knowledge based economy? (Do you see the Singapore economy being university lead or still government and MNC lead?)
    b. What about the industry? How do you think their perception of the university has changed? Do they see the university as key partners in their strategic alliances? (Today they are more interested in investing in basic research unlike in the past where they focus on applied research? Are they more interested for example in licensing technologies or provide venture support to the university today?)
    c. In one of these reports, you commented on NUS Enterprise success in creasing high tech global start ups by saying that "it is [high tech, global] businesses such as these that will bring about the next wave of growth for Singapore". Do you foresee NUS playing a very crucial role in this next wave of growth?

5. President Shih Choon Fong recently talked about wanting the NUS Alumni to play a greater role in shaping the development of the university and creating a networking environment.
    a. What do you think of this focus and how can NUS Enterprise benefit from this focus?
    b. Does NUS work with other units in the university like Office of Research or Graduate School of Integrative Sciences and Engineering as part of achieving its goals?

6. In President Shih Choon Fong's state of university address in 2002, he talked about NUS moving towards an entrepreneurial role. Being the Director of NUS Enterprise and an academic yourself,
    a. How do you feel about NUS's shift towards entrepreneurship?
    b. How do you feel about this new role with regards to its more traditional one of research and teaching? (Do you think they complement each other? Should one play a more important role? Or should the university not engage too much with the industry?

7. In the shift towards this role, there has been a lot of talk about NUS achieving Global Excellance in research, education and enterprise that NUS needs to compare itself to global standards and lead globally. They have also been changes like professors' salary being tied to their performance and the setting up NUS Enterprise to engage the university in innovation and entrepreneurship.
    a. For this, do you think that NUS is increasingly taking on a more corporate administration?
    b. Do you think that the university is ready to be evaluated like a corporate organization?

Interview Questions with Mr Wong Sang Wuoh, the Manager of NUS Venture Support, on NUS Enterprise.

1. How do you view the role of NUS Venture Support?
   a. Do you see yourself as intermediaries between the university and the industry?
   b. Are there industry players and academics who evaluate business proposals at NUS Venture Support?

2. What kind of start-ups do NUS Venture Support generally support and how are the existing starts ups that NUS Venture Support doing?

3. Does NUS Venture Support work actively with the other units of the university? How does it do?

4. Some scholars have suggested a “triple-helix” relationship between industry-university and government. How would you characterise the communication channels and relationship between the university-government-industry today?

5. What do you think of NUS taking on this new identity as NUS Enterprise?
   a. Are you aware that the university is increasingly taking on a corporate identity and administration?

6. What role do you think NUS will play in the future?